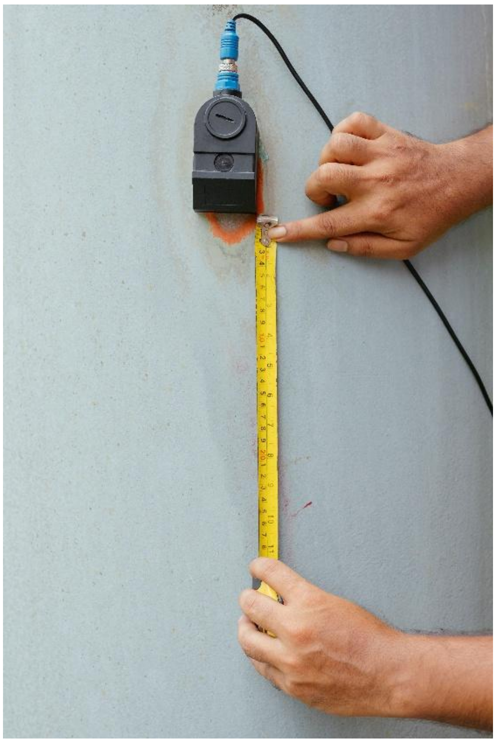
Final Report

Development of an Industry Energy Use Benchmark for Selected Processes of Fertilizer Industries in Bangladesh



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Abbreviations

AFCCL	Ashuganj Fertilizer & Chemical Company Ltd.
APC	Angewandte Physik (Applied Physics) Consulting
BCIC	Bangladesh Chemical Industries Corporation
BAT	Best Available Technology
BPT	Best Practice Technology
CUFL	Chittagong Urea Fertilizer Ltd.
EE	Energy Efficiency
EECMP	Energy Efficiency and Conservation Master Plan
GCC	Gas Combined Cycle
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
JFCL	Jamuna Fertilizer Company Ltd.
KAFCO	Karnaphuli Fertilizer Company Limited
NG	Natural Gas
OJT	On-the-Job training
P&I	Piping and Instrumentation flow Diagram
SFCL	Shahjalal Fertilizer Company Ltd.
SREDA	Sustainable and Renewable Energy Development Authority
TOE	Tons of Oil Equivalent
TICI	Training Institute for Chemical Industries
WHR	Waste Heat Recovery

1 Introduction

Bangladesh is a country with one of the highest population densities in the world. It is vital that enough food is available for the population. On the one hand, the importation of food is possible. On the other hand, however, the purchase of food from other countries consumes huge amounts of foreign exchange. And this has to be earned at first through exports. Therefore, the quantity of food that could be brought from outside into the country should be minimized.

What remains is the growing of food within the borders of Bangladesh.

Regrettably, the agricultural area to be used for food production for the large number of inhabitants is comparatively very small. Nevertheless, the supply of people with enough food must be ensured. This is one of the most important challenges of today. In order to master this tremendous task, the use of fertilizers is not only necessary, but inevitable.

In Bangladesh, an Energy Efficiency and Conservation Master Plan (EECMP) had been established, outlining the target to achieve a 20% reduction of primary energy consumption per GDP (Gross Domestic Product) by 2030, compared to the level of 2013. EECMP has a focus on several area; one of it is the fertilizer industry. As the production of fertilizers is one of the most energy intensive processes of modern manufacturing, this industry might contribute a relevant part to meet the EECMP target. The industrial sector in Bangladesh accounts for around 50% of the country’s total primary energy consumption, making it a key area for energy efficiency improvements. According to estimates, implementing energy efficiency and conservation (EEC) measures could potentially reduce national energy consumption by up to 10.5%. Within the industrial sector itself, there is a remarkable potential for energy savings, estimated at 21% of the sector’s total energy consumption. The nodal agency Sustainable and Renewable Energy Development Authority (SREDA) has identified 22 energy intensive sectors with 189 designated consumers in Bangladesh[1]. The Fertiliser Industries is one of these sectors consuming huge amounts of natural gas for the production of fertilizer in Bangladesh. With a request from SREDA, in collaboration with an international consulting firm APC and with local certified energy auditors GIZ conducted a comprehensive study aimed at establishing an energy consumption benchmark and identifying energy-saving potential in the urea fertilizer sector. This study is part of a broader effort to improve energy efficiency across Bangladesh’s industrial sectors.

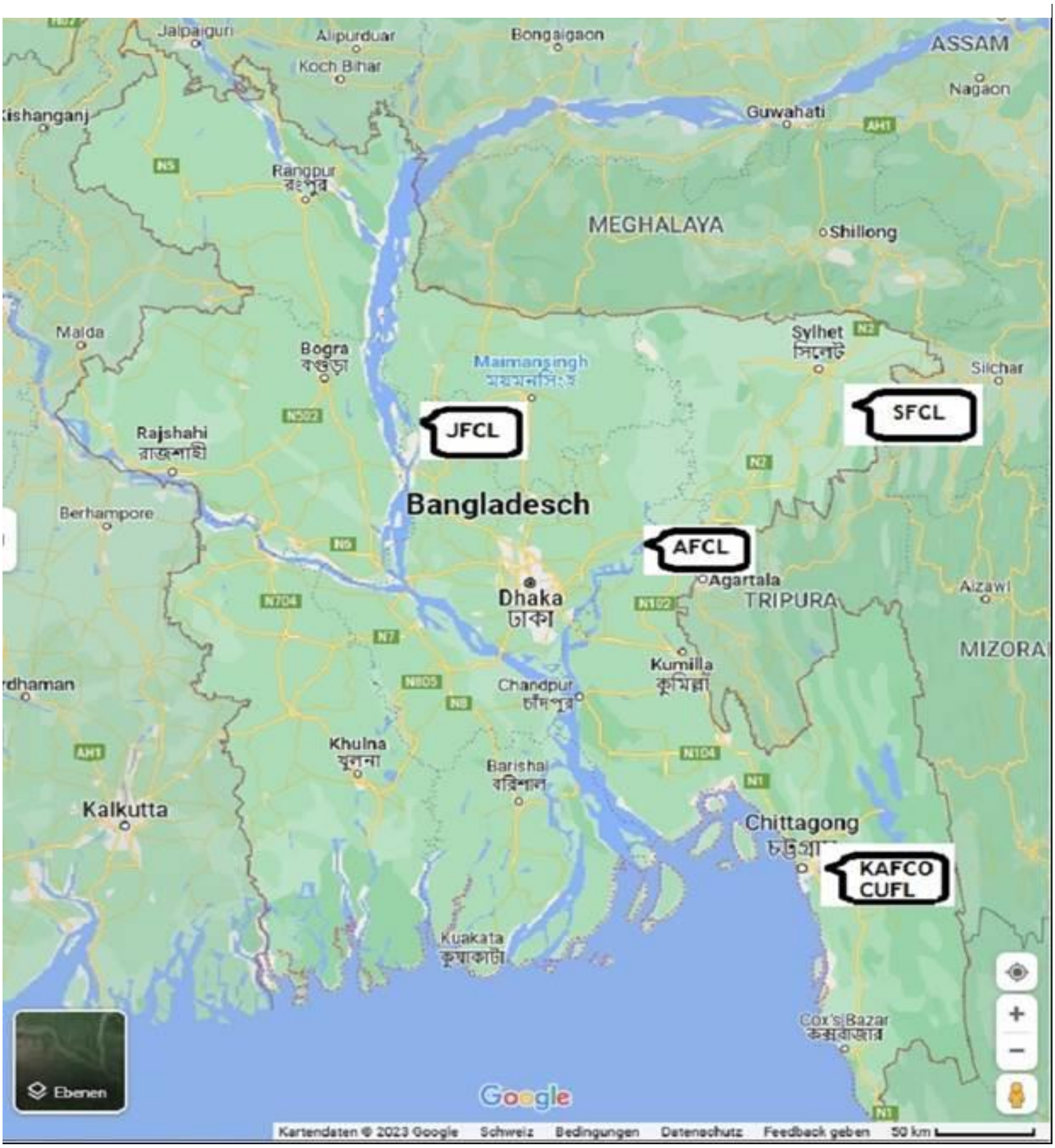
Main objective of the study “Develop an Industry Energy Use Benchmark for Selected Processes of Fertilizer Industries in Bangladesh” was to achieve this very important national target by realizing a major contribution through increased energy efficiency (EE) and energy conservation in the fertiliser industry. The best available technologies for process lines and manufactur-

[1] - - Sustainable and Renewable Energy Development Authority (SREDA)-Power Division; Ministry of Power, Energy & Mineral Resources

ing of fertilizers shall be revealed. Additionally, list of EE improvement measures are to be developed, to enhance the EE in industries. And the implementation of enhancements has to be supported and accelerated by the help of cost-benefit analyses and financial economic assessments.

At the beginning of the project, seven Fertilizer Industries were in operation; in addition, eighth factories should go into operation within a few months. The range of fertilizers manufactured in Bangladesh covers Urea, TSP (triple super phosphate), DAP (diammonium phosphate). Ammonia is produced as an intermediate product for urea fertilizer industries and one of the raw materials for the DAP industry. The majority of the companies (6 out of 8 factories) produce ammonia and urea. Due to the complexity of the process technologies involved in the production of fertilizers, it was decided to focus on the manufacturing of urea. A total of five companies did meet this boundary condition. Figure 1 shows the sites of these fertilizer industries with urea production in map of Bangladesh.

Figure 1. Map of Bangladesh and Sites of Fertilizer Industries with Urea Production



Within this context, competent engineers play a key role for conducting energy audits and uncovering weaknesses or insufficiencies in EE as well as identifying potentials for energy conservations. In addition, the energy specialists shall be in the position to develop improvements and optimizations to reduce the energy consumption of the factories or to increase the production of fertilizer without increasing the quantity of energy required for this. Furthermore, the auditors should also work out projects for EE optimisation measures to be executed, being both, technical suitable and financially profitable.

In the past, many energy auditors as well as officials of SREDA had been trained and certified as such. However, for most of them a lack of experience and practicality in energy auditing did remain. That is why the following services were to be provided within the framework of this project:

- In-depth capacity development of newly certified energy auditors,
- supervision of newly certified energy auditors on the audit activities in fertilizer industries,
- developing of a baseline energy use profile of these companies,
- compiling an energy use benchmark or energy performance indicator for this sector
- developing EE improvements for the concerned fertilizer companies and preparing their implementation in order to provide a sustainable contribution to EECMP.

In the following chapters, it is briefly recorded and illustrated how the various steps of the study have been carried out. The most important and relevant results that were achieved are documented. Furthermore, additional findings are listed which might be helpful for successfully carrying out energy audits in future and implementing the derived EE improvement measures in the audited industries. A one-day walk-through preliminary overview audit did take place at SFCL and detailed audits of 5 to 6 days in the fertilizer plants of Jamuna Fertilizer Company Ltd. (JFCL), Chittagong Urea Fertilizer Ltd. (CUFL), Ashuganj Fertilizer & Chemical Company Ltd. (AFCCL), and Karnaphuli Fertilizer Company Limited (KAFCO). The detailed reports of the latter are attached in the Final Report appendices.

2 How to Prepare oneself for a successful Energy Audit

The energy audits in the Fertilizer Industries were also used as On-the-Job training (OJT) auditors. Even the first of these OJT (at JFCL) revealed that an energy audit will only be successful, if it is carefully prepared in advance. The five steps how to proceed are listed as follows:

2.1 First of all: to understand company and processes

The company to be audited is in almost cases foreign to the auditor. The technology is new and mostly un-known. And an industry like fertilizer manufacturing is so huge and impressive that it inspires respect and sometimes even fear. It is vital and inevitable for an auditor to accept the fact that much before the energy audit can start an understanding and knowledge of the processes has to be gained. This is possible by the help of studying

- the functional description of the factory plant,

- flow chart diagrams of the processes and the production lines,
- P&I's,
- what types of energy (e.g. electricity, heat/steam, compressed air, fuels) are used,
- where in the factory, in which sections these energies are applied.

2.2 Second: uncovering where non-energy efficiency can be expected

Before entering into a factory, it is helpful to identify, where non-energy efficient sections / spots can be expected. This is possible by the help of searching for energy inefficiencies observed in earlier investigations (experience) and analyzing the technologies used in the manufacturing processes and utilities.

The following deficits in the energy systems of factories are very often detected:

- Sub-optimal use of electricity, e.g. Electric drives, power factor, lighting, ceiling fans.
- Thermal: Direct heat losses (e.g. hot water leakages), non-optimal application of thermodynamics (e.g. use of pressure reduction valves), un-used heat recovery (e.g. release of hot waters into the ambient)
- Hidden inefficiencies: Compressed air leakages (this is usually not heard), high temperature steam leakages (mostly invisible), other deficits with chilled water, thermo-oil, unburnt fuels.
- Carelessness: Repair too late or not at all (e.g. of bad insulation of hot surfaces), disregarding or neglecting maintenance.

A careful pre-analysis of the technologies used in process lines and utilities of the factory to be energy audited, very often indicates probable sections of inefficient use or waste of energy. This can be found just from studying flow charts, P&I's and other documents. Some examples:

- Electric motors are oversized and do not fit to the small power to be driven.
- The flue gas of a combustion unit is released into the atmosphere at several 100 °C.
- The blowdown valve is manually opened and closed.
- Steam for the deaerator is taken from a 180 bar steam line via a pressure reduction valve and not from an available 3 bar steam line.

2.3 Third: collecting data of the company

An energy audit has to be well prepared in advance with regard to energy and commercial data of the factory. If the energy auditor starts the audit without this information, it will not at all be effective. The relevant data can be collected by the help of questionnaires (please see Figure 2).

It is highly recommended that the information is composed not only from one year (last full commercial year) but for several years back. Only like this it is possible to uncover singular

Figure 2. Questionnaires for collecting data in preparation of energy audits (2 examples).

Type of Energy, Media	**Unit [a])**	**Fiscal Year** 2017/18	2018/19	2019/20	2020/21	2021/22	2022/23
Gas Consumption [b]) for ...							
Production	$1000\ m^3/a$						
Power generation	$1000\ m^3/a$						
Separate steam generation	$1000\ m^3/a$						
Power & steam co-generation	$1000\ m^3/a$						
Combined cycle power generation	$1000\ m^3/a$						
Others	$1000\ m^3/a$						
Total	$1000\ m^3/a$						
Diesel Consumption for ...							
Production	$1000\ m^3/a$						
Power generation	$1000\ m^3/a$						
Seperate steam generation	$1000\ m^3/a$						
Power & steam co-generation	$1000\ m^3/a$						
Power & hot water co-generation	$1000\ m^3/a$						
Others	$1000\ m^3/a$						
Total	$1000\ m^3/a$						
Electricity Generation through ...							
Gas	MWh/a						
Diesel	MWh/a						
Importation from grid	MWh/a						
Others	MWh/a						
Total	MWh/a						
Electricity Consumption for ...							
Production (Ammonia plant)							
Production (Urea plant)							
Office & non-production applictio							
Exportation to grid							
Others							
Total							
Water Consumption for ...							
Production							
Steam generation							
Others							
Total							

Relevant Data of Production	**Unit [a])**	**Fiscal Year** 2017/18	2018/19	2019/20	2020/21	2021/22	2022/23
General Information:							
Number of days of production	-						
Number of hours of production [b])	-						
Average operation capacity load [c])	%						
Average annual capacity load [d])	%						
Quantity of Production:							
Ammonia	1000 t/a						
Urea	1000 t/a						
Cost Side of Production:							
Total operating cost of company	MBTK/a						
Depreciation	MBTK/a						
Others	MBTK/a						
Total	MBTK/a						
Income Side of Production:							
Sales of Ammonia	MBTK/a						
Sales of Urea	MBTK/a						
Sales of electricity, export to grid [e])	MBTK/a						
Sales of steam, export, if so	MBTK/a						
Others	MBTK/a						
Total	MBTK/a						

[a]) Metric units: 1000 t/a = thousand tons per year; MBTK/a = Million BDT per year

[b]) Number of annual hours of production only if daily operation was not 24 hours

[c]) Percentage in the days of operation of real production vs production if operation was at layout capacicty

[d]) Percentage of real production within the year vs production if operating 365 days at layout capacicty

[e]) If different (higher) price per kWh for peak load electricity exportation, please provide data seperately

non-average years, e.g. lower production due to an impact of Corana or resulting from shortage in supply of NG (natural gas). Further on, an adequate determination of the benchmark should not be based on one year only but on the average of several years.

The relevant data an energy auditor has to acquire are:

- Energy production and consumption data per time unit (e.g., per year) of the whole plant and in the relevant section.
- Quantities of manufactured goods per time unit (e.g., per year)
- Commercial data and prices for raw materials (natural gas), energies (natural gas, electricity, fuel oil, etc.) and sold goods.

For the collection of data from the industries, questionnaires have proven to be very useful. The auditor can assemble the figures required through asking the concerned persons in the company at the beginning of the energy audit. This, however, is very time consuming as the staff of the company is on work here and, therefore, not always available for answering questions form auditors. Another option is to ask the company to fill out these questionnaires. The latter is better as the staff can do it whenever time is available outside their work at the regular job. The person also does not feel that much molested.

However, enough time should be given to the company to collect the data; some 2 to 3 weeks appear to be adequate.

2.4 Fourth: Walkthrough the factory

After having prepared himself corresponding to the above three steps, the energy auditor can set foot into the factory for first time. A walkthrough shall deliver an overview.

The walkthrough serves also as an in-depth learning and understanding of the process lines and the energy system of the factory. The control room provides an excellent opportunity to study the flow of the raw materials, intermediate and final products. Moreover, it is possible to gain a comprehension of the interaction between energy and production. Additional data can be acquired here as well.

All sections of the whole fertilizer plant are to be first time inspected, from NG entering into the facility to production of Ammonia and finally the Urea. The view and study of the technologies for storages, cooling towers and others on the site are part of this. The Utility is also quite important for an energy auditor as a relevant part of the energetic side is to be studied here. Key questions of how observed energy wastes can be overcome through potential energy efficiency improvements are to be derived and compiled.

2.5 Fifth: listing the potential biggest energy-inefficiencies

Now the energy auditor is in the position to derive a plan how to start with audit and how to carry it out. Based on the knowledge he had gained in between, it is possible now to compile the potentially biggest energy inefficiencies of the site and to develop a list for the best way to proceed.

Part of this energy audit preparation is to stipulate, where a metering of energies and of energy related data should be take place. It now also becomes clear that a selection of metering spots is inevitable, as not all of the very many components in the huge area of fertilizer production can be subject of metering in a reasonable time. It is vital, first to acquire an understanding of the technical side of the plant, then selecting the spots where to concentrate the audit, and last, resp. finally to start with metering. (Not the other way round.)

3 Results of Energy Audits in Bangladesh Fertilizer Industries

The energy audits were carried out as On-the-Job training (OJT), each from a group of 5 to 8 auditors. Almost all auditors were employed in other companies (e.g. Power Plants), very few were freelance engineers or member of an energy consulting company.

3.1 Overview of Energy Audits Carried out

Within the frame of this project, four detailed energy audits of Urea producing Fertilizer Industries were carried out.

Detailed energy audits were conducted at four urea fertilizer manufacturing industries - JFCL, CUFL, AFCCL and KAFCO. Similar was planned for SFCL in July 2024. However, the national crisis resulted in the non-operation of the plant; hence, an audit was not executed. A walk-through audit was carried out at the beginning of the project in May 2023, and relevant energy consumption data were collected from Bangladesh Chemical Industries Corporation (BCIC).

In all detailed energy audits several certified auditors - all engineers and well experienced professionals - did take place. These audits were also used as in-depth on-the-job training for these persons that they can gain experience in auditing big and complex industries. As follows a compilation of the audit activities in chronological order.

Shahjalal Fertilizer Company Ltd. (SFCL)

Date:	16 May 2023
Participants:	Four engineers of SREDA and GIZ and authors of this summary report.
Activities:	Collection of energy and production data, factory walk-through with a rough and preliminary energy audit.

Remark: A detailed energy audit was envisaged for July / August of the following year (2024); however, this could not be carried out due to shut-down of the factory; resulting from shortage of NG.

Jamuna Fertilizer Company Ltd. (JFCL)

Days: 16 to 20 August 2023

Participants: five certified energy auditors, and representatives from SREDA, GIZ and the authors of this report.

Activities: Collection of energy and production data, study of flow charts and P&I's, visit of control room to study process lines and material flow, full factory site walk-through, study of energy system and power generation, decision finding for how to check energy system data, study of application of metering equipment, preparing of metering at selected spots and carrying it out.

Remark: Use of metering equipment (Flue gas analyser, Thermal Image Camera) provided from SREDA.

Chittagong Urea Fertilizer Company Ltd. (CUFL)

Days: 25 to 30 November 2023

Participants: Five certified energy auditors, representatives from SREDA, and BCIC, TICI and GIZ.

Activities: Visit of control room to study process lines and material flow, full factory site walk-through, study of energy system and power generation, decision finding for how to check energy system data, study of application of metering equipment, preparing of metering at selected spots and carrying it out.

Remarks: Collection of energy and production data was carried out by the help of questionnaires provided to CUFL staff weeks before the audit. The auditors did study this several days before arriving at factory site. The factory had to suffer a shut-down over many weeks before the audit (due to shortage of NG). Production did start step by step in parallel with the audit.

Ashuganj Fertilizer & Chemical Company Ltd. (AFCCL)

Days: 11 to 16 May 2024

Participants: Five certified energy auditors and representatives from SREDA, and BCIC, and GIZ.

Activities: Field survey and walk-through of site, study of flow charts and P&I's, visit of control room to study process lines and material flow, study of energy system and power generation, collection of secondary data, identifying power-consuming sources, decision finding for how to check energy system data, study of application of metering equipment, preparing measurements at selected spots, measure of power through different sensor-based devices.

Remarks: Collection of basic energy and production data was carried out by the help of questionnaires that were provided to the factory staff many weeks before the audit. The auditors could study this before arriving at factory site. An extended number of metering equipment could be used. In addition to basic devices of SREDA, others (e.g. Volume Flow & Gas Velocity meter, Ultrasonic Thickness gauge, Universal Multi-Function Measuring Instrument and adapter for various probes, CO_2 Probe, Leakage Detector) had been purchased and were provided from APC, and handed over to SREDA.

Karnaphuli Fertilizer Company Ltd. (KAFCO)

Days: 6 to 11 July 2024

Participants: Five certified energy auditors, representatives from of SREDA, BCIC, and GIZ.

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Activities: Presentation and becoming familiar with the application of metering equipment. Field survey and walk-through of site, study of flow charts and P&I's, several visits of control room, study process lines and material flow, collecting of operational information and data, identifying potential power-consuming sources, detailed study of energy system and power generation, discussion and specifying how to check data of the energy system, carrying out measurements at selected spots, measuring power through different sensor-based devices, intensive discussion with company engineers on technical feasibility of EE improvement concepts and impact on production if implemented.

Remarks: Collection of basic energy and production data was carried out by the help of questionnaires that were provided to the factory many weeks before the audit. The auditors did study this in detail before arriving at factory site. The extended metering equipment of SREDA could be used.

3.2 Key Findings and Salient Results of the Energy Audits

In this chapter, the results of the 5-day detailed energy audits in the four Urea fertilizer factories are presented. This includes the observed key findings on energy inefficiency as well as the potentials of EE improvements.

Jamuna Fertilizer Company Ltd. (JFCL)

Key findings of energy inadequacies:

- In several parts of the plant damaged and uninsulated steam pipes have been identified resulting in energy leakages through heat loss.
- Various steam leakages have been observed.
- In the electrical system some energy efficiency improvements are feasible (motors and pumps, ceiling fans, lighting, air conditioners).
- Several 100 °C hot exhaust gas temperatures have been observed; this waste energy could be used through recovery.

Relevant measures to improve the energy efficiency suggested from the auditors

S.N	Measures	Estimated Energy Savings, TOE/year	CO_2 emission reduction, t CO_2/year	Estimated monetary Savings, BDT/year	Investment, BDT	Simple Payback Period, years
Los-cost Energy Conservation measures						
1.	Steam pipeline insulation	8.33	19.52	151,224.88	146,006.50	0.97
2.	Steam valves insulation	7.31	17.14	132,723.70	60,000.00	0.45
3.	Steam traps replacement	27.84	65.28	505,648.92	240,000.00	0.47
4.	Steam leakage repairing	2.71	6.35	49,171.03	50,000.00	1.02
5.	Compressed air leakage repairing	8.95	24.57	366,658.90	200,000.00	0.55
6.	Auxiliary boiler surface insulation repairing	3.52	8.27	64,021.38	58,558.89	0.91
Medium-cost Energy Conservation measures						
7.	Replacing ordinary ceiling fan by energy efficient (BLDC) ceiling fan	277.75	763.00	11,383,200.00	27,404,000.00	2.41

S.N	Measures	Estimated Energy Savings, TOE/year	CO_2 emission reduction, t CO_2/year	Estimated monetary Savings, BDT/year	Investment, BDT	Simple Payback Period, years
8.	Replacement of mercury, fluorescent and high power CFL by appropriate LED lamps	227.11	624.00	930,794.00	20,405,000.00	2.19
9.	Blowdown heat recovery for preheating makeup water for boilers	410.57	962.79	6,734,860.28	4,000,000.00	0.59
High-cost Energy Conservation Measures						
10.	Waste heat recovery boiler with GT exhaust	1,176.12	2,909.67	22,537,070.72	80,000,000.00	3.55
	Total	**2,150.21**	**5,400.58**	**42,855,373.81**	**132,563,565.39**	**3.09**

Chittagong Urea Fertilizer Company Ltd. (CUFL)

Key findings of energy inadequacies:

- Steam leakages have been observed in various parts to the factory.
- Heat losses / energy leakages through damaged insulations (e.g. steam pipes, valves, flanges) and completely non-insulated hot surfaces.
- Utility boiler with inefficient combustion.
- Exhaust gas temperatures of boilers are over 200 °C; i.e. loss of thermal energy.

- Boiler blowdown carried out manually without metering blowdown requirements and without heat recovery, hence, resulting in a considerable loss of energies.
- An energy saving option is available through cleaning the condenser (fouling and scaling) of the Ammonia plant.
- No waste heat recovery in several parts of the factory.
- Some electrical appliances and applications are not energy efficient; this could be improved through state-of-the-art systems (e.g. lighting, ceiling fans).

Relevant measures to improve the energy efficiency suggested from the auditors

SL No.	Measures	Estimated Energy Savings, TOE/year	CO_2 emission reduction, t CO_2/year	Estimated Monetary Savings, BDT/year	Investment, BDT	Payback period (years)
Low-cost Energy Conservation measures						
1.	Improvement of Combustion Efficiency of Utility Plant Boiler	692	1,965.15	46,238,803	1,000,000	0.02
2.	Replacement of Faulty Steam Traps.	49	137.93	1,301,184	480,000	0.37
3.	Providing Insulation on Exposed Utility Boiler Drums.	8	23	177,892	300,000	1.69
4.	Providing Insulation on Exposed Steam Valves and Flanges	22	62.51	3,074,373	400,000	0.13

SL No.	Measures	Estimated Energy Savings, TOE/year	CO_2 emission reduction, t CO_2/year	Estimated Monetary Savings, BDT/year	Investment, BDT	Payback period (years)
5.	Providing Insulation on Exposed Steam Distribution & Condensate Return pipelines.	480	1,362.81	9,085,372	1,200,000	0.13
6.	Reducing the Air Compressor Discharge Pressure.	5	44.40	644,744	-	-
Medium-cost Energy Conservation measures						
7.	Optimize Boiler Blowdown by Installing Automatic Blowdown Control Valves at Utility Boilers.	6,472	18,380.47	270,301,067	3,000,000	0.01
8.	Installation of Automatic Blowdown Control Valve to minimize Blowdown Loss at NH3 plant Aux Boiler.	149	424.29	4,781,864	4,000,000	0.84
High-cost Energy Conservation measures						
9.	Refurbishing/ Modification of Feed Water Economizer	6,472	18,380.47	144,160,569	60,000,000	0.42
10.	Use of Boiler blowdown water to preheat polisher water	256	727.21	10,694,240	10,000,000	0.94

SL No.	Measures	Estimated Energy Savings, TOE/year	CO_2 emission reduction, t CO_2/year	Estimated Monetary Savings, BDT/year	Investment, BDT	Payback period (years)
11.	Using Boiler blowdown water as Cooling Tower make-up water	-	-	24,480,000	10,000,000	0.41
12.	Cleaning Of Condenser (Fouling & De-Scaling) Of NH_3 Plant.	5,162	14,660.37	114,983,319	100,000,000	0.87
13.	Preheating condensate water extracting waste heat from NH_3 Plant Boiler Blowdown.	199	566.39	5,747,878	20,000,000	3.48
14.	Improve existing lighting systems by more energy efficient LED lamps	129	1,176.66	15,454,602	11,222,320	0.73
15.	Replacement of existing Ceiling fans by more energy efficient fans	81	733.65	7,920,000	32,500,000	4.10

Ashuganj Fertilizer & Chemical Company Ltd. (AFCCL)

Key findings of energy inadequacies:

- Steam leakages have been observed in various parts to the factory.
- Heat losses / energy leakages through damaged insulations (e.g. steam pipes, valves, flanges) and completely non-insulated hot surfaces.
- Boiler blowdown carried out manually without metering blowdown requirements and without heat recovery, hence, resulting in a considerable loss of energies.

- Blowdown water is wasted up to now.
- Compressed air leakages.
- Flue gas temperatures high up to 200 °C; hence, there is a loss of thermal energy.
- Condensers and other heat exchangers in inefficient operation due to fouling and deposits within the tubes
- Power factor is low and, in addition fluctuating between 0.49 and 0.92.
- Operation of inefficient electric drives.
- Some electrical appliances and applications are not energy efficient and could be improved through state-of-the-art systems (e.g. lighting, ceiling fans).

Relevant measures to improve the energy efficiency suggested from the auditors

SL No.	**Measures**	**Estimated Energy Savings, TOE/year**	**CO_2 emission reduction, t CO_2/year**	**Estimated Monetary Savings, BDT/year**	**Investment, BDT**	**Payback period (years)**
Low-cost Energy Conservation measures						
1.	Energy saving opportunities from uninsulated pipeline (calculation based on 1m^2 surface area)	2	14	31,440	9,200	0.29
2.	Energy saving opportunity by systematically detect compressed air leaks using an ultrasonic measuring device	-	-	115,000	460,000	4.00

SL No.	Measures	Estimated Energy Savings, TOE/year	CO_2 emission reduction, t CO_2/year	Estimated Monetary Savings, BDT/year	Investment, BDT	Payback period (years)
3.	Energy saving opportunity by introducing Jockey pump instead of continuous running of motor driven fire pump in the fire water system	24	186	2,441,120	350,000	0.14
Medium-cost Energy Conservation measures						
4.	Minimize boiler blowdown by installing automatic blowdown control valves.	689	1,664	812,000	4,000,000	4.93
5.	Boiler blow down water use as cooling tower make-up water	-	-	484,500	2,000,000	4.13
High-cost Energy Conservation measures						
6.	Energy saving opportunities from cooling & water intake pumps	81	611	8,297,318	11,025,000	1.33
7.	Installation of power factor improvement (PFI) plant	86	670	21,450,600	15,000,000	0.70

SL No.	Measures	Estimated Energy Savings, TOE/year	CO_2 emission reduction, t CO_2/year	Estimated Monetary Savings, BDT/year	Investment, BDT	Payback period (years)
8.	Energy saving opportunity by installation of roof top solar panel (PV system) instead purchasing electricity	138	1,078	14,160,369	83,809,000	5.92
9.	Energy saving measure: Analysis of replacing inefficient motors with efficient (IE3 94.6% efficiency) motors.	292	2,274	29,900,939	100,000,000	3.34
10.	Energy saving due to cleaning of the condenser of CO_2 compressor	524	980	7,223,607	20,000,000	2.77
11.	Improve existing lighting systems by more energy efficient LED lamps.	129	909	13,162,776	23,481,200	1.78
12.	Replacement of existing Ceiling fans by more energy efficient fans	102	719	10,406,880	42,000,000	4.04

Karnaphuli Fertilizer Company Ltd (KAFCO)

Key findings of energy inadequacies:

- Very few steam leakages (almost non) have been observed in the factory.
- In one section of the facility is was observed that flue gases released to the ambient have temperatures around 200 °C.

Relevant measures to improve the energy efficiency

SL No.	Measures	Estimated Energy Savings, TOE/year	CO_2 emission reduction, t-CO_2/year	Estimated Monetary Savings, BDT/year	Investment, BDT	Payback period (years)
Low-cost Energy Conservation measures						
13.	Energy Conservation by replacing the cooling tower's aluminum fans with fiberglass reinforced plastic (FRP) fans	11.5	27.004	287,277	1,500,000	5.22
Medium-cost Energy Conservation measures						
14.	Installation of Inlet Guide Vane (IGV) at the inlet of air compressor for controlling the air intake	87.24	205	2,180,924	3,000,000	1.38
15.	Heat recovery by covering with thermal insulation of the uninsulated steam valve and flanges (for per m^2 of insulation)	1,085.1	2,550	27,127,570	4,241,160	0.16

SL No.	Measures	Estimated Energy Savings, TOE/year	CO_2 emission reduction, t-CO_2/year	Estimated Monetary Savings, BDT/year	Investment, BDT	Payback period (years)
High-cost Energy Conservation measures						
16.	Installation of rooftop solar panel	-	-	7,568,901.9	50,000,000	6.61
17.	Energy Saving Scope by refurbishing or modifying feed water economizer	19,128.4	44,952	478,209,956	80,000,000	0.17

- Heat recovery from the hot flue gases released up to now. However, a pre-heating of feedwater was found to result in an impact on following heat exchangers; this would require a new lay-out of the subsequent components. Hence, this type of heat recovery seems not to be feasible. But there are other options (still remained to be worked out in depth and analyzed with regard to feasibility), e.g.
  -> pre-heating of combustion air,
  -> pre-heating of fuel,
  -> using the heat for drying, of so at KAFCO,
  -> generating low pressure steam for de-aerating,
  -> generating mid pressure steam (5 to 10 bar), using this in steam turbine(s)
  for driving pumps, compressors or so, or
  generating some additional electricity.
- Utility: Replacing traditional electricity generation with steam water cycle by GCC technology; this might result in big reduction of NG consumption of the factory. However, up to now there is no basic engineering and no financial feasibility assessment.

4 Energy Benchmark

Benchmarking is a strategic process that involves measuring the performance of one company against another company or a set of companies in the same market. The idea behind this is to work out a key performance indicator of manufacturing entities and to provide this for a comparison. Benchmarking is mostly applied for energy consumption analyses. However, the method can also be used for other purposes.

The benchmarking of energy performance of industrial enterprises is a tool to step by step improving the energy efficiency in the concerned industry sector. The method has been used from various organisations and also published (e.g.: Andersson, E., Arfwidsson, O., Thollander, P., 2018, Benchmarking energy performance of industrial small and medium-sized enterprises using an energy efficiency index: Results based on an energy audit policy program, Journal of Cleaner Production, 182, 883-895).

An energy benchmark of an industry sector will give the top management/owner a better understanding of their/his performance through providing the potential for energy efficiency improvements. In this chapter the efficiency of NG consumption of the audited Fertilizer Industries for producing Ammonia and Urea are derived and compared in a benchmark.

Parameter of Benchmarking in Fertilizer Industry:

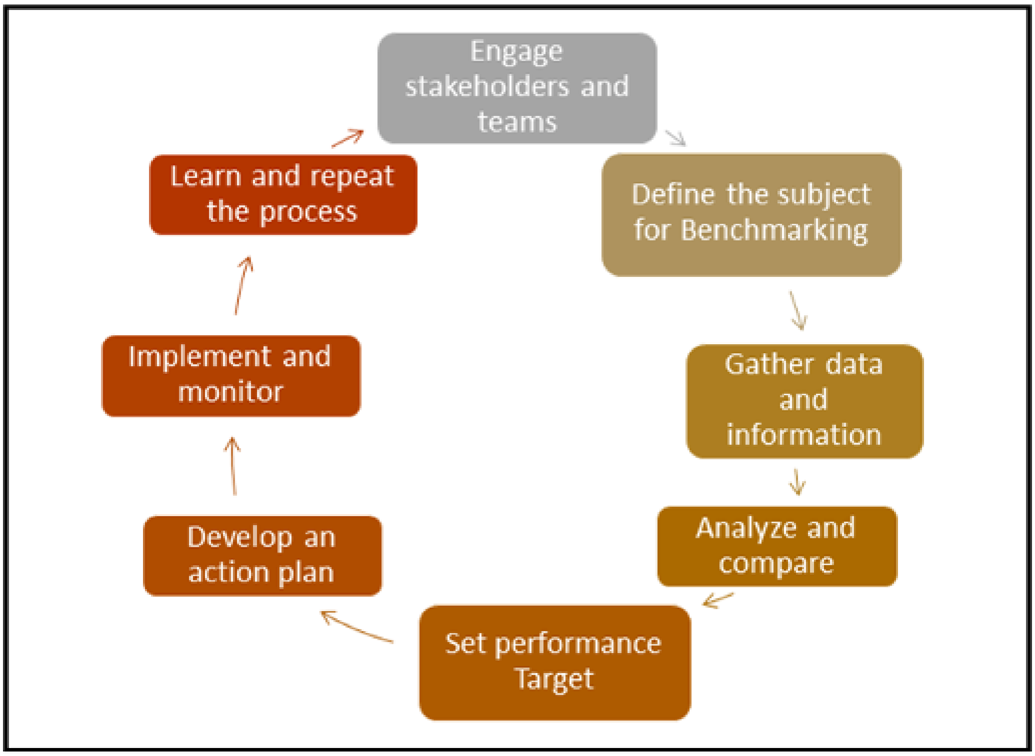
The Energy Consumption (GJ)/Ton of Ammonia or Energy Consumption (GJ)/Ton of Urea could have been used as the Parameter to Benchmark. As all factories under this study evaluate their performance in terms of Energy Consumption per ton of Urea, this value (GJ/ton Urea) has been selected as the parameter of our Benchmarking. Figure 5 mentions a few international benchmark values for both ammonia and urea.

Methodology of Benchmarking Study:

Figure 3 summarizes the methodology to conduct the benchmark study. During the calculation of specific energy consumption and evaluation of benchmark, following steps were followed:

1. Collect data of total (for both production and steam/power generation) natural gas consumption from grid.
2. Collect data for total electricity taken from grid.
3. Collect data for total electricity export to the grid (if any).
4. For simplicity all types of energies could be converted to a common unit like Giga Joule (LHV) / Year
5. Calculate total energy consumption.
6. Collect data of total production of ammonia and urea.
7. Calculate the specific Energy Consumption in GJ/MT of Urea for each factory.
8. Identify the Best Available Technology (BAT) and Best Practice Technology (BPT)
    a. BAT = The lowest SEC of all analysed companies is defined as best available technology (BAT) and
    b. BPT = The second lowest SEC is defined as best practice technology (BPT).

Figure 3. Steps of Benchmarking study



4.1 Results of Benchmark Study in Bangladesh:

The production and energy consumption data of five (5) fertilizer factories were collected and benchmark study was conducted. Figure 4 shows the participatory factory and their design production capacity.

Figure 4. Fertilizer Factories in Bangladesh and design capacity for Ammonia and Urea.

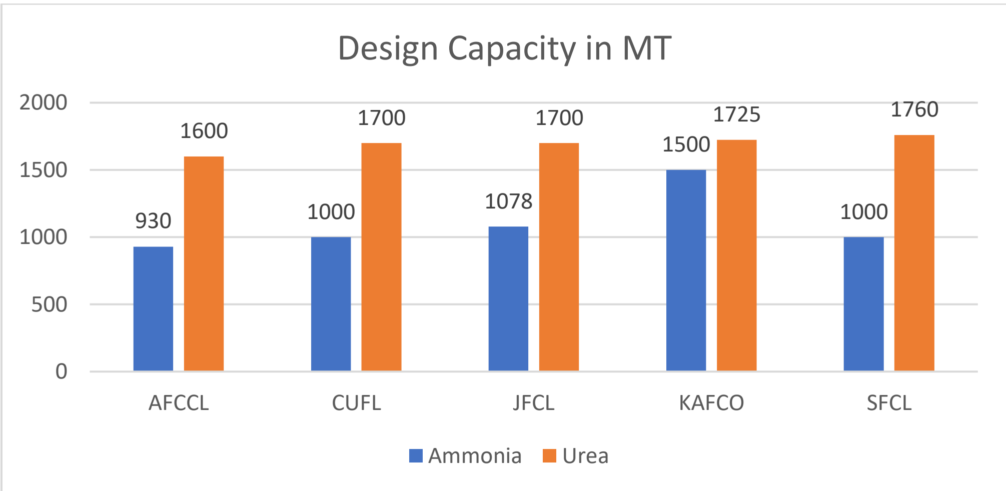
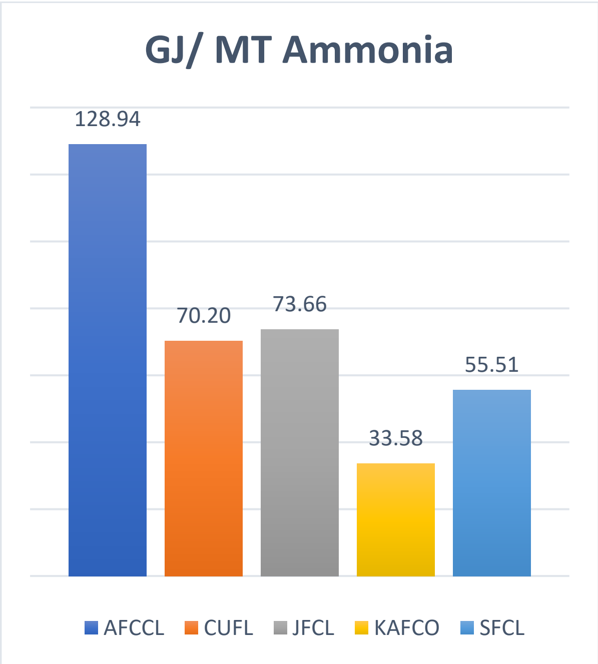


Figure 5 shows the specific energy consumption for both ammonia and Urea. According to the UNIDO (United Nations Industrial Development Organization), a typical benchmark curve plots the efficiency of plants as a function of the total production volume from all other similar plants.

Figure 5. Specific energy consumption for Ammonia and Urea.



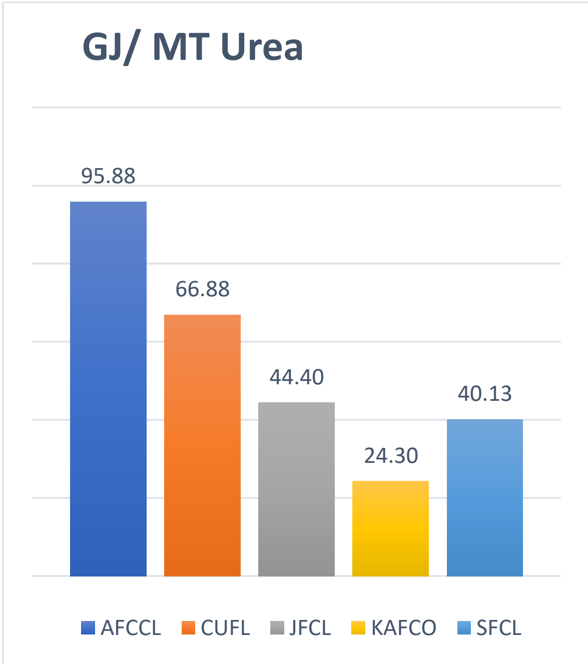
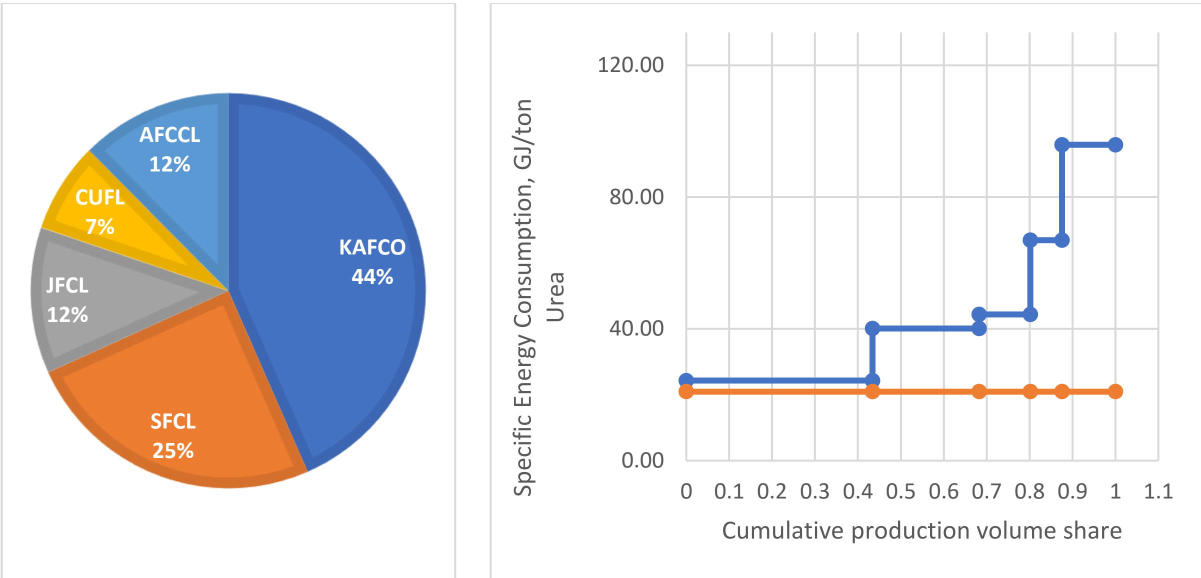


Figure 6b shows the benchmark curve (specific energy consumption of the analyzed companies per ton of fertilizer produced (GJ/t Urea) as a function of the production volume share) for the fertilizer industry for the total energy consumption. The most efficient plants of Bangladesh are represented to the left and lower part of the curve, and the least efficient plants to the right and upper part of the curve. The most efficient plant of the analyzed companies in Bangladesh, KAFCO, has a specific total energy consumption of 24.3 GJ/t Urea and a production volume share of 43 % in the fiscal year 2022-23 (
Figure 6a). This value defines the national best available technology (BAT) value. The orange line indicates the best international BAT value corresponds to a specific total energy consumption of 20.92 GJ/t Urea[2]. The second lowest specific energy consumption in this curve is defined as the national best practice technology (BPT) value. The national BPT value is 40.13 GJ/t Urea which is for Shahjalal Fertilizer Company Ltd. (SFCL).

[2] Fertilizer Sector Report, India
https://keralaenergy.gov.in/files/Resources/Fertilizer_Sector_Report_2018.pdf

Figure 6. a. Production share of factories and b. Benchmark Curve



a. Production share   b. Benchmark Curve

4.2 Saving Potential of factories in Bangladesh:

Different energy saving scenarios until 2040 were drawn under this study. The four scenarios considered under this study are:

- Baseline efficiency: Energy efficiency improves at a rate of 0.2 % a year.
- 1% saving: Energy efficiency improves at a rate of 1 % a year.
- 2% saving: Energy efficiency improves at a rate of 2 % a year until they reach to the global BAT value (if any).
- BPT scenario: All plants are operating at the current levels of BPT by 2040. This is equivalent to an energy efficiency improvement of 5.5 % a year in the period 2024 to 2040. The BPT is the lowest BPT, either on national or international level. For the fertilizer sector this is the national BPT value of 40.13 GJ/t urea.

The formulas for saving calculations are as follows[3]:

On the national level, the Annual saving potential of each company(x) =
(SEC of Company x - BAT national) * Annual production(t) of Company x

Potential of the Whole Sector = (International BAT – weighted SEC of the Analyzed Companies) * Total Production of the Whole Sector

[3] Source: Industrial Energy Efficiency Project, Benchmarking Report for the Fertilizer Sector, UNIDO. https://downloads.unido.org/ot/38/87/3887086/Benchmarking%20Report%20Fertilizer.pdf

Figure 7 shows energy saving potential in tera joule of Bangladeshi fertilizer factories compared to the current performance level of KAFCO. The energy saving potential of the whole fertilizer sector of Bangladesh is 27.55 TJ compared to the current best performing factory in the world.

Figure 7. Energy saving potential per year of Bangladeshi fertilizer factories

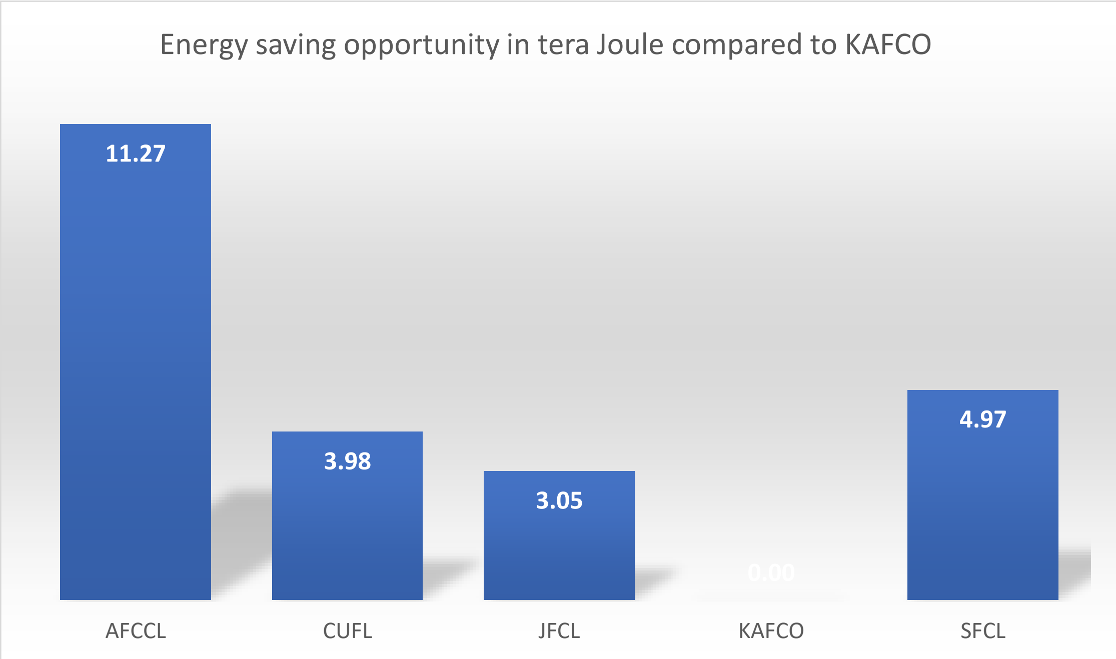


Figure 8. Energy saving potential in tera joule for four different energy saving scenarios.

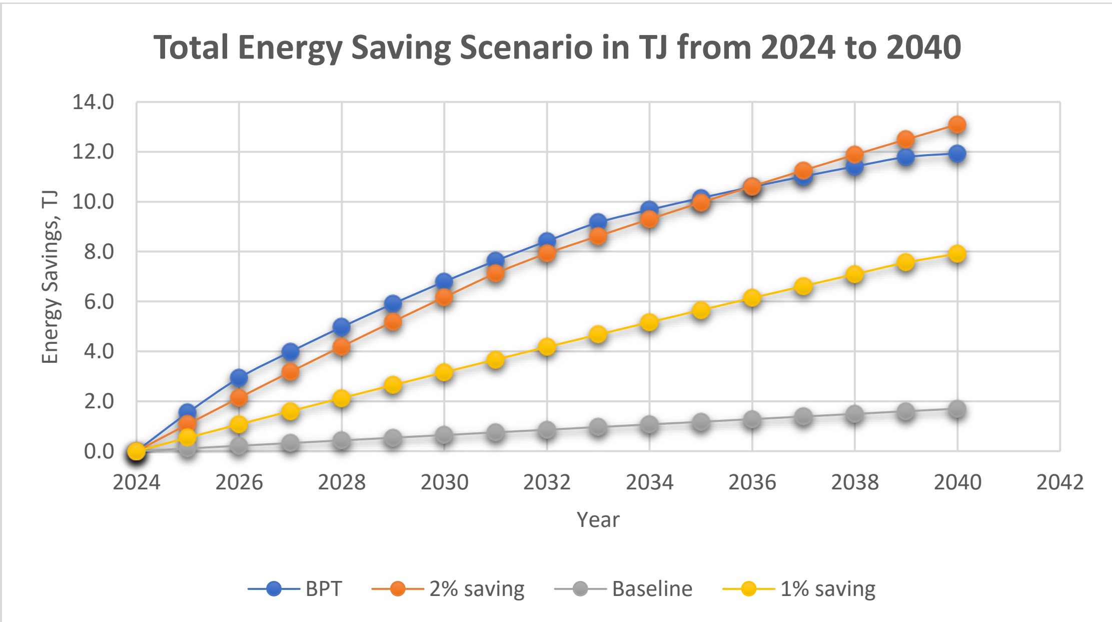
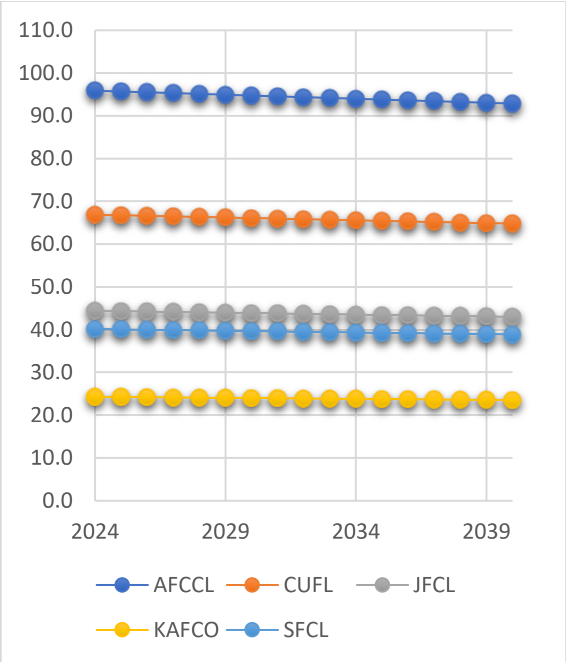
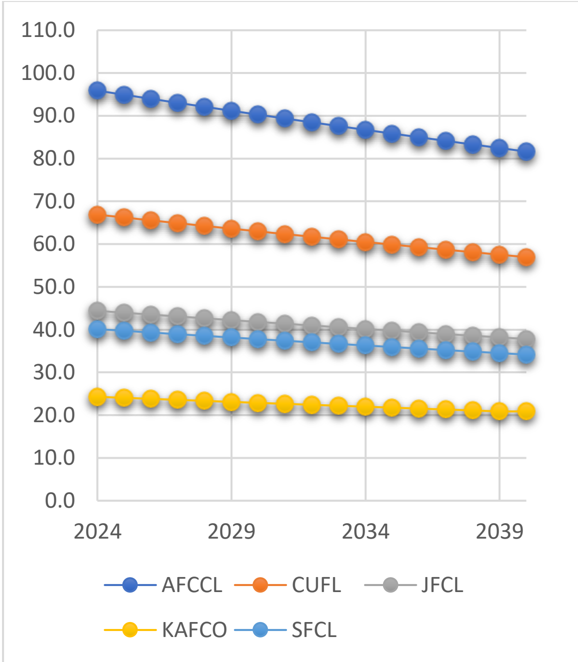


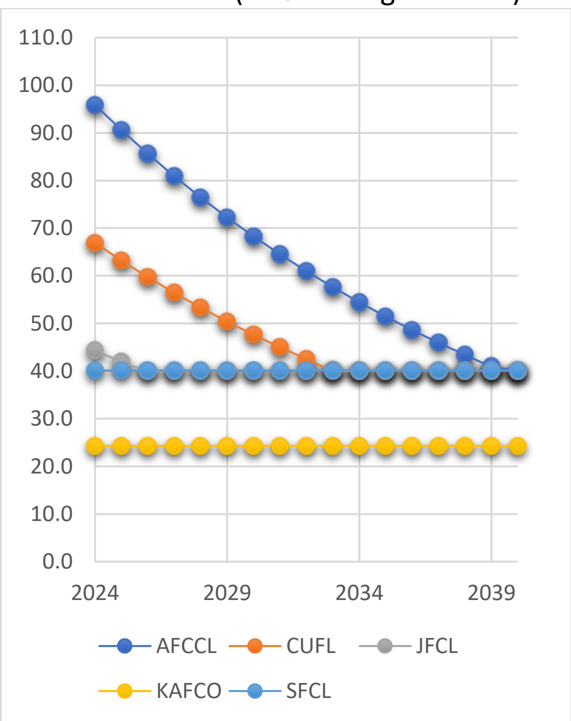
Figure 9. Specific energy consumption of Urea production from 2024 to 2040 to achieve the desired energy saving for four energy savings scenarios.



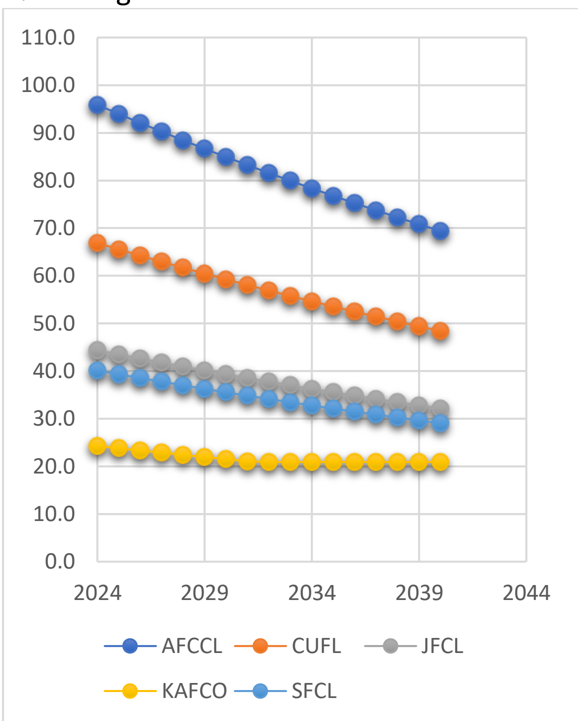
Baseline scenario (0.2% saving scenario)



1% saving scenario



BPT Scenario



2% saving scenario

The Figure 8 and Figure 9 show the energy saving estimates and specific energy consumption of Urea production from 2024 to 2040 to achieve the desired energy saving for four energy savings scenarios discussed above. These are just for illustrative purpose only. Each company may choose its own target depending on the strength and limitations of the company. Four energy audits have been conducted in AFCCL, CUFL, JFCL, and KAFCO to identify the scope for improvement in those factories.

The audit findings are summarized in previous section. Factories may achieve their desired performance by implementing the recommendations proposed by the auditors. For a few cases, further analysis may be required to come to a final decision for implementation. Moreover, as a designated consumer (all fertilizer factories except Ghorashal Palash Fertilizer Public Limited Company, commissioned in June 2024) are identified as designated consumers by SREDA), each factory will require to conduct these energy audits at a certain interval to identify the improvement opportunities and to achieve the desired performance by 2040.

Summary remarks

- There is a relevant potential to reduce the specific NG consumption for Ammonia and Urea production through EE improvement measures in all audited Fertilizer factories.
- Interruptions of the fertilizer productions because of stop of NG supply result in a higher specific energy consumption, hence, the gap to the target value of the energy benchmark is bigger and, respectively, more unfavourable.
- The Fertilizer Industry is not in the position to guarantee and secure the supply of NG continuously and un-interrupted to their factories. They cannot replace NG with another material, as NG is the raw material for the production of Urea. However, the generation of electricity for the grid - consuming huge quantities of NG - could be modified: If this power generation was shifted from NG to other sources, e.g. CO_2 free technologies like solar, wind, biomass, coal with carbon capture and storage technology, Uranium (share of renewables is still 4.65 % in national energy mix[4]), much more NG could be allocated to the fertilizer production. And the production would be more energy efficient.
- Recommendations of how to improving the specific NG consumption per ton of product through reducing energy losses and improving EE have been worked out: The basic engineering is documented, and the financial feasibility of such projects as well. Still the implementation remains to be carried out.

[4] SREDA | National Database of Renewable Energy (https://www.renewableenergy.gov.bd/index.php?id=7), retrieved on 20/11/2024

5 Lessons Learned – Relevance of Production and Energy Efficiency

At the beginning of this chapter, it is to be emphasized that -as mentioned in chapter 3 - the project of carrying out energy audits in Fertilizer Industries was a training program for auditors. Although all of them were certified, the majority had very little or no practical experience with audits - especially not with audits of very large and complex industrial facilities. These aspects should be accounted for when studying the detailed audit reports of the factories.

Some five energy auditors did take part in the detailed factory audits, each of which lasted a full week. However, not only auditors (and the two trainers) participated, but also additional persons from third party like SREDA, GIZ and BCIC. (The presence of BCIC and SREDA representatives was crucial for getting audit data from the factories). Therefore, the entire group comprised up to 15 people or even more. And all walk around, and they ask the staff this and that - and the concerned person of the factory whose task is to do his job in the factory might get the impression to be molested. One can imagine that all this can result in triggering something like a feeling of an invasion among the companies' employees.

From this, one of the lessons learned is that

- the group of auditors should not be bigger than necessary,
- when conducting an energy audit for a fertilizer factory (or another of comparable size), the on-site presence must not be longer than necessary,
- the auditors have to account for day to day working obligations of the staff of the audited facility,
- the impression of molesting the counterpart engineers and other staff working in the company should be avoided.

How to meet with these objectives? Examples for Fertilizer Industries and others of comparable complexity and size:

- The composition of the group of auditors is relevant. It should contain the knowledge of mechanical, electrical, and chemical engineers, i.e. three to four engineers in total would be sufficient.
- If the auditors are well informed on the technology before first time stepping into the site of the factory, a total presence of three (to max. five) days should be enough. The days do not have to be consecutive.
- It is inevitable that, prior to starting the audit on site, the auditors did have gained a full understanding of the company and its manufacturing processes and its energy flows as well as the related key data (corresponding to chapter 2).

Another lesson learned is that the energy auditors, in general engineers coming from outside to a factory, and the relevant engineers working there (among them their counterparts) have a very different way of thinking:

- The auditor's brain is full of energy; energy is the most important, guiding the auditor's activities; other issues are side aspects for him.
- In the brain of the company engineer, the priorities are weighted completely different: for him the production is the most important. If an electric drive is no more working, it must be replaced as fast as possible, even if the replacement motor is much too big (and inefficient); most important is that the production goes on. If a 3 bar steam supply fails and cannot be repaired, but steam from nearby 60 bar steam line is available,this will be used with a pressure reduction valve (although highly inefficient) in order to re-run the production as fast as possible.

  Energy is a very side aspect for the company engineer.
- It is obvious that energy auditors and company engineers might very often have different - sometimes even controversial – priorities and objectives.

This results in the fact that the auditor and the company engineer are talking past each other. For the one energy efficiency is the only relevant, for the other it is the production. If so, energy inefficiency findings from audits will not meet with an open ear. An identified huge heat loss in the factory production lines and the auditor's suggestion to improve it (what is presented in the audit report as an EE implementation project) has little or no chance of being implemented. How to overcome this dilemma?

- An auditor must be aware of the fact that production has the upper most priority for each company manufacturing fertilizers or anything else.
- On the other hand, a company engineer should also realize that energy inefficiency is a waste of energy, what is a waste of money, jeopardizing the competitiveness of his company and even might threaten his workplace he is paid for.
- While working out measures or projects to overcome energy inefficiencies or straight energy losses, the auditor must check if there is an impact on the production. If so, another solution has to be developed which doesn't interfere into production.
- The audit report should not only present EE improvements suggested from the auditors, but also explain that (and how) the implementation does not interfere into production.
- It might be, that an EE improvement cannot be implemented without touching the production. If so, a derivation has to be done how to minimize the impact on the production. This is inevitable. And an in-depth discussion with company engineers is required, as well as an explanation in the report.
- Experience shows that in some cases EE improvements even have a positive impact on production (e.g. higher throughput, better quality). If so, this should be presented in the audit report as well. It will facilitate the implementation of such measures considerably.

6 Energy Audit is not the End but the Beginning

Worldwide countless energy audits have been conducted and still are. Nevertheless, only little change in energy systems of companies to improve their efficiency can be observed. It is a fact, unfortunately, that the valuable work of energy auditors to improve the EE, what is also documented in their audit reports, becomes forgotten after a while. And nothing happens.

The **key insight** from this is, regrettably, that

> An energy audit is worth nothing, if its result is not converted into engineering of energy efficiency improvement projects and their implementation.

The general question is:

> Is the energy audit report the end of work of an auditor?

And the answer is:

> **No! The Audit Report is the Beginning!!**

How to overcome the problem that after energy audits of industries and audit reports with numerous suggestions how to increase the energy efficiency, more or less no implementations take place? As the auditors are capable to develop EE improvement projects, their skills cannot be doubted. Hence, other or new or better audits will not solve the problem. What is needed instead is a **Change in Mindset:**

> The **objective is not the energy audit per se**, but that the energy conservation and the **energy efficiency** in the Fertilizer Industries (and others) is **really implemented**.

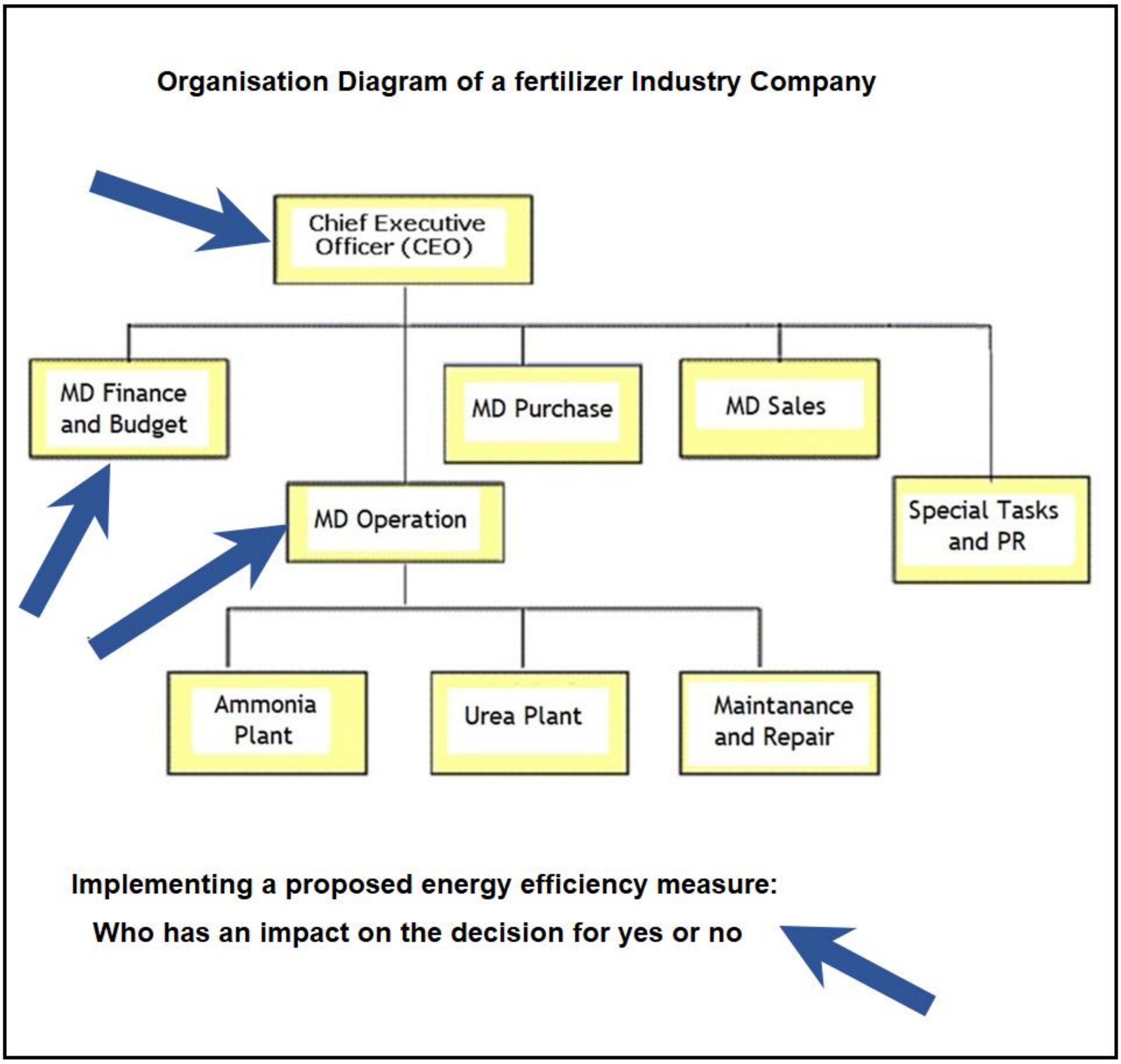
The **method** of how this can be achieved through in-depth training and how it was carried out by consultants of this project is summarised below:

- The main objective that needs to be achieved with top priority, is that energy efficiency improvement measures have to be implemented in the fertilizer plants. Not only the energy auditor should have this in mind permanently but also the company itself, the industry management, BCIC / Ministry of industries. This is the top guideline.
- Energy auditors must also have stored in brain and in subconscious that the delivery of an audit report is not the end of a job but the beginning of energy efficiency improvements in the audited facility.
- Energy auditors must not stop work after having documented the audit results, but continue with the development of EE improvement projects to be implemented.

- These EE improvement projects (e.g. heat recovery from hot flue gases, GCC technology for power generation, electric drives efficiency measures), are to be developed with basic engineering, detailed engineering, and the assessment of profitability.
- Although energy auditors do not have authority for decision making, they are the ideal persons to promote the implementation of EE improvements: After an energy audit, they have an understanding of both, the manufacturing processes and the engineering side of EE improvement projects - and also how to implement it without interfering into production.

After the projects will have been developed and made available to the companies, the role of the energy auditor changes. He should / has to become a promotor of the implementation: his

Figure 10. Relevant persons in a factory who might take EE decisions.



main task now is to convince the decision makers of the company (CEO, MD, Chief of Operation, Chief of Finance) through explaining the advantageousness of the improvement projects not only from the technical and energetic point of view but also with respect to the financial benefit, i.e., less costs and higher profit.

The relevant persons who decide if energy efficiency improvements (resulting from the audit) shall be implemented or not, are show in Figure 10.

The new, additional role of the energy auditor still has to be established. This should become and be a common-sense understanding in Bangladesh between manufacturing companies, industry organisations / associations like BCIC, governmental authorities and institutions, and the auditors.

If so, the Bangladesh can develop itself into a leader for energy efficiency in industries through not only auditing but also - different from the very most others in the world - implementing the EE improvement measures.

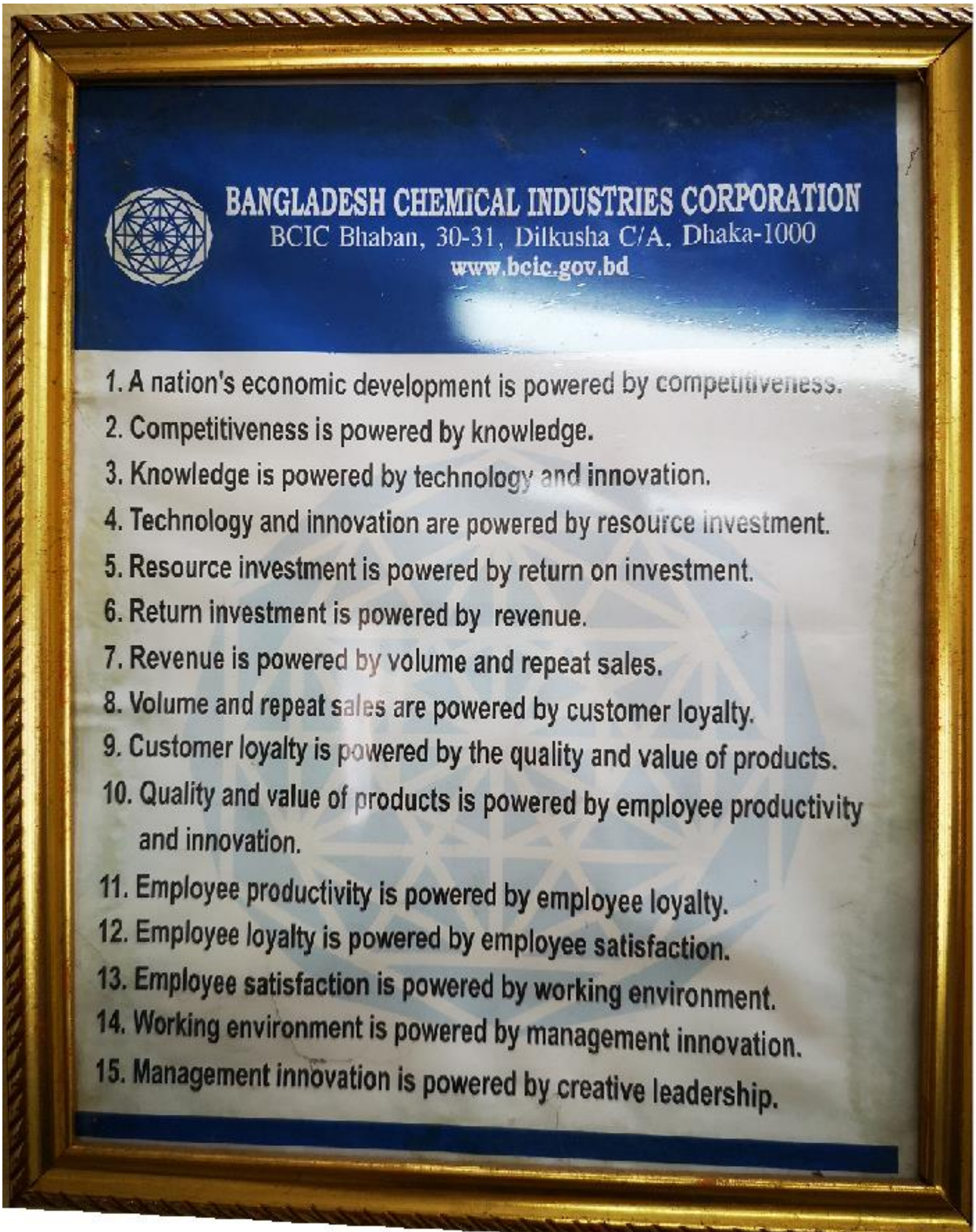
Like this, the country will be in the position to resume and continue the successes of the old days, when all over the world one used to speak of the ‘Golden Bengal’. Today’s successes result from industries manufacturing good products and being competitive in the world. A relevant part of this is the energy efficient production. This is very important for the fertilizer industry, as their manufacturing process is highly energy intensive.

The fertilizer industry is also necessary for the survival Bangladesh because it ensures the food supply for the people in a country with one of the highest population densities in the world. Some fertilizer companies have been producing Urea for over 40 years, although their plants were only designed for 30 years of operation. This definitely results from an excellent work-force what can only be called "good". In-between, however, the raw material (natural gas) for the production of urea and the generation of the energy is becoming increasingly scarce in Bangladesh - and therefore more expensive. Hence, it is difficult for the companies to compete with manufacturers abroad who do not suffer from such high gas prices.

This is why old skills are required: inventing and engineering something that fertilizer product-ion becomes more efficient, becomes better. "Better" is the enemy of "good." "Better" means being able to produce the same quantity of urea with less natural gas.

This is exactly what the energy auditors do. They prepare and help to improve the competitive-ness of the fertilizer industry (see Figure 11) - and thereby helping the whole country.

Figure 11, The Economic Development of Bangladesh is powered by Competitiveness, © BCIC.



Annexes

Annex A: Energy Audit Reports of JFCL

Annex B: Energy Audit Reports of CUFL

Annex C: Energy Audit Reports of AFCCL

Annex D: Energy Audit Reports of KAFCO

Annex A

Energy Audit Reports of JFCL

ENERGY AUDIT REPORT

for

Jamuna Fertilizer Company Limited

Tarakandi, Sarishabari, Jamalpur

Bangladesh

Prepared by

[Sustainable and Renewable Energy Development Authority (SREDA)]

Report Date: [07/11/2024]

Acknowledgement

Sustainable and Renewable Energy Development Authority (SREDA) would like to express their sincere gratefulness to the senior management team including the technical team and other officials for initiating the move for carrying out energy audit in the Jamuna Fertilizer Company Limited located at Tarakandi, Sarishabari, Jamalpur. It makes us happy that the management of the factory is very much cooperative with the audit team. The audit team acknowledges with thanks the tremendous support provided by the officials of JFCL during the entire audit process. It is only due to this support that we were able to perform the targeted tasks in a very short period of time.

Executive Summary

The Jamuna Fertilizer Company Limited has taken an initiative to improve its energy efficiency. In that respect SREDA certified energy auditors under guidance of GIZ consultant has conducted the energy audit in the factory premises. This program aims for the significant improvement of Energy Efficiency & Conservation (EE&C) and at the same time, decrease of CO_2 emissions and energy costs. An important step in this program is the execution of an energy audit to identify EE&C options that fit with in this ambition.

The energy audit was conducted for five days from 16th to 20th August 2023. It covered survey of the whole industrial facility for study, observation, data collection related to process and utility systems. Necessary and possible measurements were also taken. Calculations are made to identify the losses, current efficiency, potentials of energy saving, reduction on environmental footprint and related economic analysis.

The Jamuna Fertilizer Company Limited has been producing Urea fertilizer from natural gas through several operations. The plant has two sections, one is Ammonia and another one is Urea. The factory consumes electricity and natural gas as its main source of energy. Electricity comes from steam turbine generators, gas turbine generator and national grid. Natural gas is used as fuel as well as raw materials. Thermal energy demand is fulfilled by boilers. The plant has waste heat recovery boilers from the process section and auxiliary boilers burning of natural gas.

Table 1: Current energy intensity status

Time Period	Gas Consuming Intensity (mcf/ton urea)
Fiscal year 2017/18 to 2022/2023	40.42

Current energy efficiency of the systems based on historical data period of 2017/18 to 2022/23.

Table 2: Current energy efficiency of the utilities

Name of the Appliance	Energy Efficiency (%)
Auxiliary boiler plant	84%
Gas turbine	32%

1.1. Key observations

Thermal and Mechanical system:

- Auxiliary Boilers are equipped with super heater and air preheater which reduces exhaust temperature thus huge energy is saved. Oxygen percentage was found around 3.5% at the flue gas of the Auxiliary Boilers.
- Condensate form the process side is recovered.
- Blowdown is system is continuous and flash steam from the blowdown is recovered.
- Many steam valves are not insulated properly, and damaged steam piping insulation was observed in many places.
- Many steam leakages are found.
- Some of the steam traps are malfunctioning.
- Boilers surface insulation is well, but some hot spots were identified.
- Currently gas turbine's exhaust waste heat is not recovered.
- Many compressed air leakages were found.

Electrical system:

A. Electrical power generation/sources

1. The facility generates its electricity from steam turbine and gas turbine generator by using natural gas.
2. There are two (2) units of steam turbine generator of rated capacity of 8.0MW (6.6kV) each and one unit of gas turbine generator of rated capacity of 4.0MW (6.6kV).
3. The facility has a grid power supply from 47km away with a sanctioned load of 4MW. It remains almost unused. Moreover, it frequently shows faulty (ground fault) as per management information. This may be for long distance line and improper protection arrangement.
4. Steam turbines are used as base power at a capacity of 4.0MW (50% of the rated capacity) each to produce a total of 8.0MW. According to operator information, for loading above 5.0MW, the steam turbines face high vibration, load halting etc.
5. Gas turbine is used as auxiliary source of power and run at a load of 2.0MW to 3.5MW (highest). The exhaust flue gas of the gas turbine generator is unused.
6. The total load demand is 10.80MW with an average requirement of 10.60MW.

7. The load demand for different sections are for general service (0.80MW), water system (0.50MW~0.60MW), jetty (0.40MW~0.50MW), ammonia production (0.80MW~0.85MW with steam turbine driven motor and 1.0MW~1.20MW with electric motor driven), cooling system (2.60MW~2.77MW), urea production (4.0MW), solid handling section (0.15MW), admin (0.20MW), housing (0.18MW~0.22MW) and natural gas booster (0.90MW~1.0MW).
8. The minimum demand charge for grid power is BDT 250,000.00 per month.
9. The subsidized tariff of natural gas is BDT 16.00/Nm3 while it is BDT 30.00/Nm3 for all industrial consumers.
10. Natural gas consumption by gas turbine generator is 658Nm3 to generate 1MW of electricity.
11. Natural gas consumption by steam turbine generator is 363Nm3 to generate 1MW of electricity.
12. The cost of electricity (considering only cost of fuel-natural gas) generated by gas turbine generator is BDT 10.53/kWh and by steam turbine generator is BDT 5.81/kWh. The actual cost of electricity will be higher considering other costs (lube oil, spare parts, maintenance, operator salary etc.). The average cost of electricity has been considered BDT 10.00/kWh in calculation of payback period.
13. There is no energy meter for residential consumers. In general BDT 120.00 per month is charged for each house.

B. Observation and findings- lighting

1. Different types of lamps are used in this facility for production light, warehouse light, bulk area go-down light, yard light, streetlight, boundary light, office light and residential light.
2. Mercury lamps (400W and 250W) are used as production light, warehouse light, bulk area go- down light, yard light, streetlight, and boundary light.
3. Photocell control (setting undefined) system is incorporated with streetlight, yard light and boundary light to save power by automatic day night operation.
4. Fluorescent lamps (T8/36W~40W) are very common throughout the facility from production area, office area, general area, and residential area etc.
5. Fluorescent lamps are used either in single luminaries (1 * T8) or double luminaries (2 * T8) with traditional magnetic ballast.

6. Considering energy efficiency, fluorescent lamps are gradually replacing retrofit LED lamps (18W) in T8 shape. Around 75% of the total fluorescent lamps have already been replaced by retrofit LED types.
7. Compact fluorescent lamp (CFL/18W) and LED bulb (10W~18W) are very common in household applications especially in residential area.
8. High power compact fluorescent lamp (CFL/65W) is used in streetlight of residential area.
9. The housekeeping of lighting luminaires is very poor (dusty) which reduces the light output from the lamps.
10. The operational time for production area and bulk area go-down is continuous (24h/d), for office area is average 12h/d and residential area is 18h/d.
11. The approximate quantity of lamps - mercury vapor (400W)/366nos, mercury vapor (250W)/535nos, ESL (65W)/130nos, fluorescent lamps (23W&40W)/8,519nos.

C. Observation and findings- ceiling fan

1. Traditional ceiling fans are used in factories, offices, and residential areas. The average rating of the ceiling fan (56”) is 85W to 120W.
2. About 300nos of ceiling fan are in factory area and about 3,916nos are in residential area.
3. The average operational hour is 12h/d to 18h/d.

D. Observation and findings- home appliances

1. Several types of home appliances of different category and types are widely used in residential areas such as- refrigerator and freezer, washing machine, television, electric iron, room heater etc.
2. The average operational hour is 2h/d to 18h/d.

E. Observation and findings- motors and pumps

1. Many motors and pumps are used in this facility for continuous, intermittent, and standby operation.
2. The motors are of different capacity (0.2kW~1185kW) with two (2) different operating voltage. The operating voltage of the motor is 415V for capacity up to 150kW and 6.6kV for capacity above 150kW.

3. The pumps are of electric driven type or steam turbine driven type.
4. The rated efficiency of motors is about 76.5%~92.8% as per installation manual. Efficiency has been degraded to some extent due to ongoing 35 years of operation.
5. Motors and pumps are of good brands form EU and JAPAN while installed on 35 years ago. Few of them have been repaired and replaced against malfunctioning or damaged.
6. The average operational hour is 8h/d to 24h/d.

F. Observation and findings- HVAC system and air conditioners

7. A good number of discrete air conditioner of different capacity (1TR~8TR) and several types (window type, split type, floor standing type, ceiling suspended type, duct type) are used both in plant side (office and production area) and residential side in this facility.
8. A total of 230nos (1TR-36, 1.5TR-44, 2TR-74, 4TR-34, 4.5TR-6, 5TR-20, 6TR-3 and 8TR-13) of discrete air conditioners are installed within the premise.
9. Most of the air conditioners are of good brand from EU and Japan and are in operation for last 35 years. A few of them have been replaced by new model of good brand available in the local market.
10. There are also two (2) units of chiller system of capacity of 60TR each (total 120TR) are in operation. Each 60TR chiller unit consists of four (4) units of compressor of capacity 15TR.
11. The average operational hour is 8h/d to 20h/d in summer season.

Energy Savings Measures or Recommendations

Thermal and Mechanical System:

1. Install a waste heat recovery boiler to harness energy from the gas turbine exhaust.
2. Blowdown heat can be recovered to preheat makeup water of the boilers.
3. Repair insulation on steam pipe, steam valves & flanges to prevent heat loss and improve energy efficiency.
4. Many steam leakages were found. Repair all the steam leakages to prevent energy wastage and optimize the performance of the steam system.
5. Repair steam traps which are not functioning properly to minimize heat losses.
6. Boilers surface insulation is well but some hot spots were identified.

7. The total required steam from the Waste Heat Recovery (WHR) boilers is designed to be around 200 tons per hour. However, the current steam production from the WHR boilers does not meet the design conditions. This discrepancy is likely due to scaling or fouling occurring in the heat exchange tubes. To rectify this issue and ensure optimal heat transfer and system efficiency, it is imperative to implement a heat exchanger cleaning program immediately.
8. Many compressed air leakages were found. Repair all the compressed air leakages to prevent energy wastage and optimize the performance of the compressed air system.
9. Implement quarterly maintenance programs throughout the year to proactively address potential issues, optimize equipment performance, and extend the operational life of the system. These maintenance programs should encompass a comprehensive examination of all relevant components, including valves, pipes, boilers, and heat exchangers, to identify and address any issues promptly. Regular maintenance helps prevent unexpected breakdowns and ensures the system operates at peak efficiency.

Electrical System:

1. The provision of non-utilized and problematic grid power option should be re-evaluated to save BDT 250,000.00 per month. Grid power can also be easily utilized for full residential area and general usage (light, fan, office, common space etc.). Moreover, during shutdown time, maintenance time while no production process is activated, grid power will be more cost-effective solution to supply power for residential area as well as general usage of production area. Operation of gas turbine generator or steam turbine generator in partial load is not efficient in respect of fuel consumption as well as the safety of the turbine also.
2. The electricity generation by gas turbine generator should be minimized as the electricity generation cost is higher (about double that of steam turbine).
3. It will be better to replace the gas turbine generator with a steam turbine generator as it is feasible for both technical point of view as well as fuel consumption cost even in subsidized tariff. The overall financial feasibility in respect of investment, operation & maintenance cost, IRR, ROI etc. should be properly evaluated to do so.
4. It would be better to install an energy meter for each domestic user to measure the electricity consumption per month. Though a very negligible amount (present electricity tariff- BDT 120.00/month) is charged for each consumer, energy meter will motivate the user to become conscious of misuse/wastage of electricity that will lead to a remarkable amount of energy savings from residential/housing area.
5. Regular and effective housekeeping can improve the light output from the lamps.

6. Mercury lamps (400W and 250W) should be replaced by equivalent LED type lamps (to get the same light output) that will save a remarkable amount of electrical energy.
7. High power CFL (65W) lamps should be replaced by equivalent LED type lamps (to get the same light output) that will save a remarkable amount of electrical energy.
8. Increasing awareness of energy conservation to avoid unattended and unnecessary usage of light can save a good amount of electrical energy. Alternatively, automation of light (by occupancy sensor/day night sensor/timer) in office and common areas to avoid unattended and unnecessary usage can also save a good amount of electrical energy.
9. Replacing the traditional ceiling fan (85W~120W) with the energy efficient ceiling fan (35W~40W) can save remarkable amount of electrical energy.
10. Increasing awareness of energy conservation to avoid unattended and unnecessary usage of light, fans and air-conditioner can save a good amount of electrical energy. Alternatively, automation of such appliances (by using occupancy sensor/timer) to avoid unattended and unnecessary usage in office and common areas can also save a good amount of electrical energy.
11. Increasing awareness of energy efficiency and encouraging the home user to use energy star leveled models of home appliances will bring a positive impact on overall electrical energy savings.
12. Besides, the efficiency level, operational loading pattern of motors and pumps is very important to ensure energy efficiency. Without measuring power consumption against loading pattern for 24 hours of operation of any motor or pump, it is not possible to make any recommendation. The shortage of time for auditing as well as very insufficient number of required types of measuring tools for such a large number of motors and pumps is the main limitation in this regard.

To provide brief description of the process followed for identification of energy efficiency measures and their techno-economic assessment and summary table for the identified and recommended measures for implementation.

Table 3: Summary of the EE&C measures with financial analysis

S.N	Type of measures	Measures	Estimated Energy Savings, TOE/year	CO_2 emission reduction, tCO_2/year	Estimated monetary Savings, BDT/year	Investment, BDT	Simple Payback Period, years
1	High cost	Waste heat recovery boiler with GT exhaust	1,176.12	2,909.67	22,537,070.72	80,000,000.00	3.55
2	Medium cost	Blowdown heat recovery for preheating makeup water for boilers	410.57	962.79	6,734,860.28	4,000,000.00	0.59
3	Low cost	Steam pipeline insulation	8.33	19.52	151,224.88	146,006.50	0.97
4	Low cost	Steam valves insulation	7.31	17.14	132,723.70	60,000.00	0.45
5	Low cost	Steam traps replacement	27.84	65.28	505,648.92	240,000.00	0.47

S.N	Type of measures	Measures	Estimated Energy Savings, TOE/year	CO2 emission reduction, tCO2/year	Estimated monetary Savings, BDT/year	Investment, BDT	Simple Payback Period, years
6	Low cost	Steam leakage repairing	2.71	6.35	49,171.03	50,000.00	1.02
7	Low cost	Compressed air leakage repairing	8.95	24.57	366,658.90	200,000.00	0.55
8	Low cost	Auxiliary boiler surface insulation repairing	3.52	8.27	64,021.38	58,558.89	0.91
9	Medium cost	Replacement of ordinary ceiling fan by energy efficient (BLDC) ceiling fan	277.75	763.00	11,383,200.00	27,404,000.00	2.41
10	Medium cost	Replacement of mercury, fluorescent and high power CFL by appropriate LED lamps	227.11	624.00	930,794.00	20,405,000.00	2.19
		Total	**2,150.21**	**5,400.58**	**42,855,373.81**	**132,563,565.39**	**3.09**

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Abbreviations and definitions

BDT	:	*Bangladesh Taka*
EnPI	:	*Energy Performance Indicator*
EMO	:	*Energy Management Opportunity*
GCV	:	*Gross Calorific Value*
GJ	:	*Gigajoule*
KJ	:	*Kilojoule*
MJ	:	*Megajoule*
NG	:	*Natural Gas*
RH	:	*Relative Humidity*
SCM	:	*Standard Cubic Meter*
SCMPH	:	*Standard Cubic Meter Per Hour*
SCMPD	:	*Standard Cubic Meter Per Day*
SCMPY	:	*Standard Cubic Meter Per Year*
SEC	:	*Specific Energy Consumption*
WHR	:	*Waste Heat Recovery*
tCO_2	:	*Ton of carbon dioxide*
O_2	:	*Oxygen*
CO_2	:	*Carbon dioxide*
CO	:	*Carbon mono oxide*
T_{flue}	:	*Flue gas temperature*
T_{air}	:	*Ambient air temperature*
ΔT	:	T_{flue}- T_{air}

1 Introduction

In collaboration with SREDA, Power Division, and GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit), Bangladesh, an extensive training program titled "On-the-Job Training on Energy Audit and Benchmarking for Fertilizer Industries" was conducted from August 16 to August 20, 2023, at the premises of Jamuna Fertilizer Company Limited in Tarakandi, Sarishabari, Jamalpur, Bangladesh. Jamuna Fertilizer Company Limited, a government-owned entity established in 1991 with technical support from Mitsubishi Heavy Industries, is a major player in Bangladesh's fertilizer sector. Currently facing production shortages due to insufficient natural gas supply, the company is operating at 1200 metric tons per day, below its capacity of 1700 metric tons per day. Responsible for supplying fertilizers to 20 districts in Northern Bangladesh, the company's reduced output raises concerns for regional agricultural productivity. Addressing the natural gas supply challenge is critical to sustaining the company's vital role in supporting the agricultural sector and ensuring food security in Northern Bangladesh.

Recognizing the critical role of energy in propelling the development of Bangladesh, particularly within the fertilizer industry, this training program aimed to enhance the efficiency and effectiveness of energy utilization. As Bangladesh stands as one of the world's most populated countries, the demand for energy, especially in the production of Urea for crop cultivation, is substantial. However, in light of global energy limitations, the imperative is to ensure a judicious and sustainable use of these resources.

Fertilizer factories, being significant energy consumers, underwent a meticulous energy audit to establish standardized benchmarks for energy utilization. This report encapsulates the findings and recommendations resulting from the audit, providing a comprehensive overview of the current energy landscape within the fertilizer industry in Bangladesh. The objective is to facilitate informed decision-making and promote sustainable practices that align with global energy conservation goals.

Through this report, we aim to contribute valuable insights into optimizing energy consumption, fostering sustainability, and supporting the continued development of Bangladesh. The knowledge and skills imparted during the training program are integral to the successful implementation of energy audit practices, fostering a culture of energy efficiency and responsibility within the fertilizer industry.

1.1. General facility details and descriptions

Name of the facility	Jamuna Fertilizer Company Limited
Address/Location	Tarakandi, Sarishabari, Jamalpur
Internet Web Page	https://jfcl.gov.bd/
Sector/Type of the facility	Urea fertilizer manufacturing plant
Contact Person (Management)	Md. Fazlul Haque
Designation	Deputy Chief Engineer & Plant In-charge (Ammonia)
Phone	+880 1945-201737
E-mail Address	fazlul1977haque@gmail.com

SALIENT FEATURES OF JFCL

1.	Project Name	Jamuna Fertilizer Co. Ltd.	
2.	Location	Tarakandi, Sarishabari, Jamalpur.	
3.	Project area	Factory area	76 acres
		Housing area	61 acres
		Jetty area	21 acres
		Heavy duty road area	23 acres
		Railway area	12 acres
		In front of factory area	7 acres
		Total area	200 acres
4.	General Contractor	Mitsubishi Heavy Industries Ltd. & Mitsubishi Corporation, Japan.	
5.	Technical Adviser	Unico International Corporation, Japan.	
6.	Process Licensor	Ammonia	Haldor TopsØe, Denmark.
		Urea	Snamprogetti, Italy.
		Granulation	Hydro Agri, Netherlands.
7.	Financier	Foreign Currency	OECF, Japan.
		Local Currency	Bangladesh Govt. (Through ADP/ BCIC)
8.	Project cost	A. Foreign Currency	Tk. 93551.88 Lac
		B. Local Currency	Tk. 32702.67 Lac
		Total	Tk. 126254.55 Lac
9.	Debt-Equity Ratio		90 : 10
10.	Capital	Approved	Tk. 75000.00 Lac
		Paid-up	Tk. 5.00 Lac
11.	Period of construction		36 Months
12.	Project Implementation	Start : 13th November, 1989 Completion : 25 th December 1991	
13.	Start of trial production		31 December, 1991
14.	Start of commercial production		1st July, 1992
15.	Production capacity	Ammonia	: 1078 MTPD : 355740 MTPY
		Granuled Urea	: 1700 MTPD : 561000 MTY
16.	Power generation capacity	STG	2x8 MW
		GTG	1x4 MW
		DEG	700 KW
		PDB (Standby)	3 MW
		DEG (Standby)	2 x 640 KW
17.	Quality of Urea	Nitrogen (Min[m].)	46.0% by wt.
		Moisture (Max[m])	0.3% by wt.
		Biuret (Max[m])	0.9% by wt.
		Formal- dehyde (Max[m])	0.55% by wt.
18.	Granule size	Above 4.75mm	10% (Max[m])
		Above 2.00mm	93% (Min[m])
19.	Usage Ratio	NG/ MT NH_3	830 NM^3
		NG/ MT Urea	621 NM^3
		CO_2 / MT Urea	0.75 MT
		NH_3 / MT Urea	0.575 MT
		Formaldehyd/MT Urea	0.0055MT
20.	Storage capacity	Bulk Urea	50,000 MT
		Bagged Urea	10,000 MT + 4,000 MT
		Liquid Ammonia	10,000 MT
21.	Handling capacity	Bagging	3600 MTPD
		Railway wagon loading	2880 MTPD
		Truck loading	1440 MTPD
22.	Manpower (Approved-2013)	Officer	338
		Staff	326
		Worker	387
		Total	1051
23.	Recreation Facilities	Officers Club, Employees Club, Ladies Club, Auditorium, Tennis & Football Grounds etc.	
24.	Others Facilities	School & College, Medical Centre, Employees Co-operative Depertmental store, Mosque, Hafizia Madrasa, Lotery Hazz scheme, Staff Bus, Play ground, Fire Brigade, etc.	

1.2. Energy Auditors details

Energy Auditor	SREDA Audit Team along with GIZ consultants
Team Members	(1) Helmut Körber, PhD, Consultant (APC Angewandte Physik Consulting AG) (2) Md. Solayman Kawsher (Certified Energy Auditor, SREDA, Bangladesh, E.A(EEE)-0300036-06, Consultant (APC Angewandte Physik Consulting AG) (3) Md. Abdullah Al Mamun (Assistant Director, Energy Audit & Accreditation, SREDA)

	(4) Muhammad Zakir Hossain (Consultant - Nippon Koei, Mitsubishi Research Inc., Certified Energy Auditor, SREDA, Bangladesh, E.A(ME)-0200063-008) (5) Md. Abdul Alim (CEO, Wellmake Engineering & Technology, Certified Energy Auditor, SREDA, Bangladesh, E.A(EEE)-0300043-016), Consultant (IPC-GmbH) (6) Sumit Kumar Saha (Chief Executive Officer, Future Business Support Centre, Certified Energy Auditor, SREDA, Bangladesh, E.A(ME)-0200020-005) (7) Md Abu Sayeed (Executive Engineer, EGCB, Certified Energy Auditor, SREDA, Bangladesh, E.A(EEE)-0400041-025) (8) Md. Mahbubur Rahman (Assistant Professor, ME (DUET), Certified Energy Auditor, SREDA, Bangladesh, E.A(ME)-0400012-021)

Figure 1: Audit Team

1.3. Objective of Energy audit

The main objective of this energy audit is to identify the energy efficiency and conservation potential of the plant and to calculate the Gas Consuming Intensity in the unit of m3/ton of Urea for understanding the present energy consumption status with respect to the other similar plant. Detail objectives are as follows:

A. Conducting Comprehensive Energy Audit:

- Undertake a thorough energy audit to analyze various energy use scenarios within fertilizer manufacturing processes.
- Establish standard benchmarks for energy consumption to gauge efficiency and identify potential areas for improvement.

B. Identifying Energy Saving Opportunities

- Assess existing systems to identify opportunities for energy conservation and formulate strategies to optimize energy usage.
- Develop recommendations for enhancing energy efficiency in line with sustainability goals and global energy constraints.

C. Technical Knowledge Transfer

- Facilitate technical know-how exchange among participants, including professionals and fertilizer process engineers.
- Promote a collaborative learning environment to enhance participants' understanding of energy audit methodologies and best practices.

D. Knowledge Sharing for Process Engineers

- Provide a platform for process engineers involved in fertilizer production to share insights and experiences related to energy management.
- Foster a community of practice where participants can discuss challenges and successes, contributing to continuous improvement in energy efficiency.

E. Awareness Program for Energy Handlers

- Conduct an awareness program specifically tailored for individuals directly involved in handling energy for the production of Urea.
- Emphasize the importance of responsible energy management, highlighting the role each individual plays in achieving overall energy efficiency objectives.

1.4. Scope of Energy audit

Scope of the work is to analyze the energy consumption pattern of different systems of the plant based on energy bills and field measurement data. Identify EE&C potential projects for improving energy efficiency and reduction of GHG emission.

1.5. Energy Audit Methodology (flow chart with descriptions)

The following figure illustrates the methodology adopted for carrying out the walk-through energy audit.

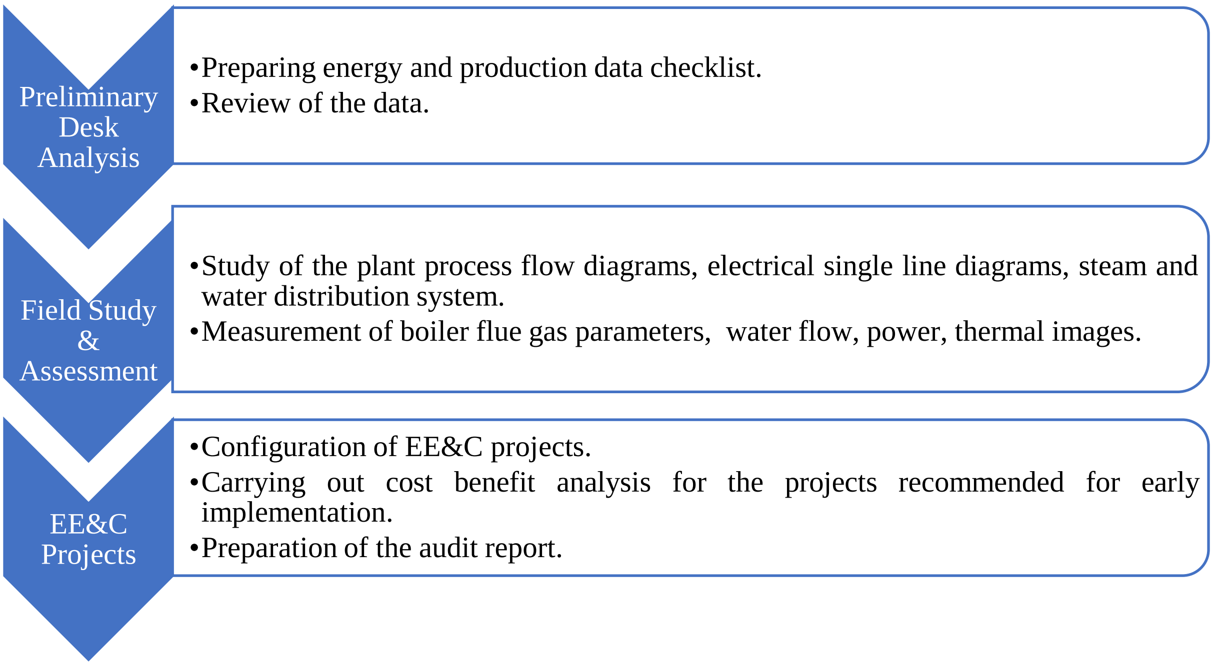
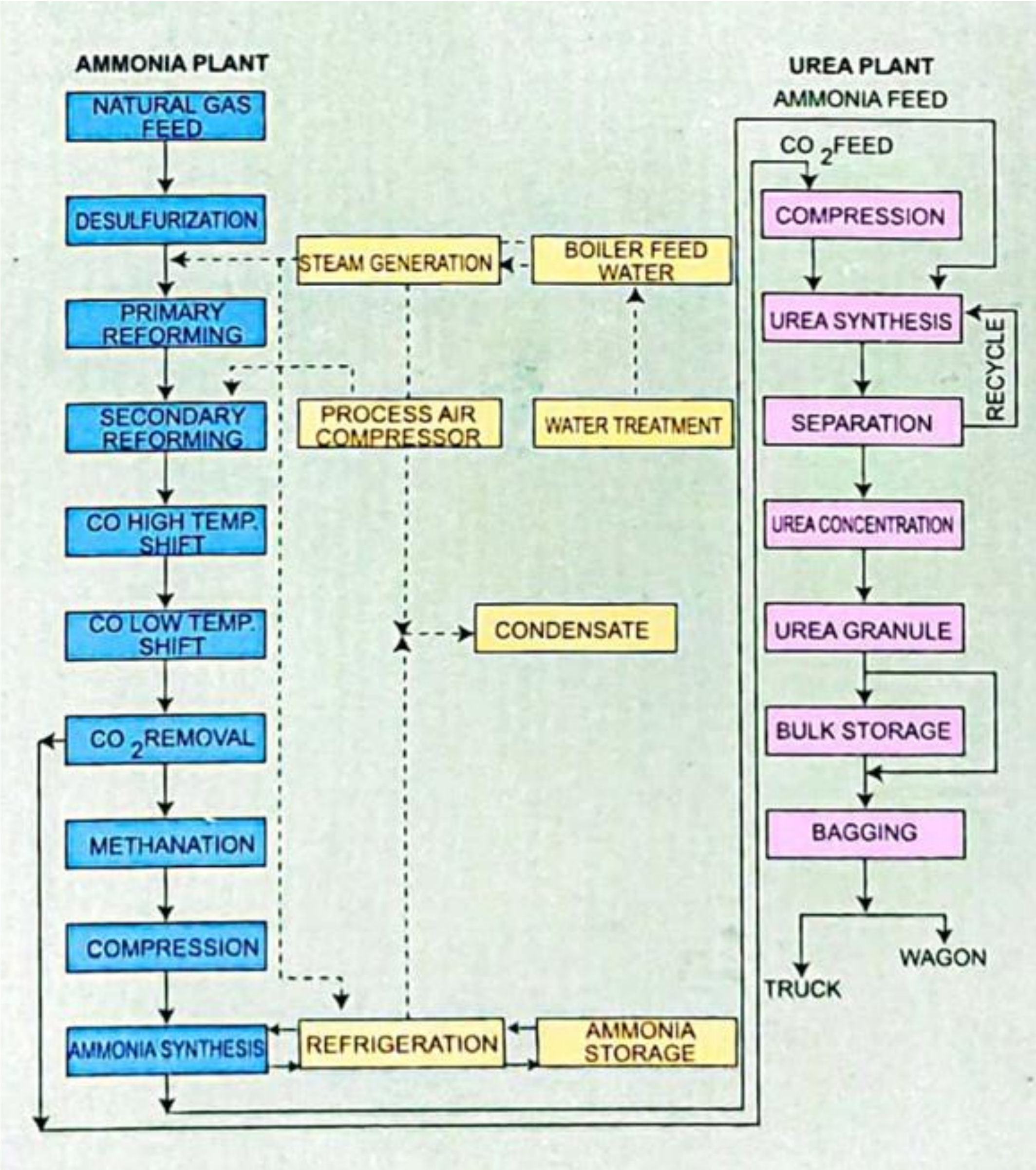


Figure 12: Methodology for the energy audit

1.6. Production Process Description

1.6.1. Breif description of products manufacturing process

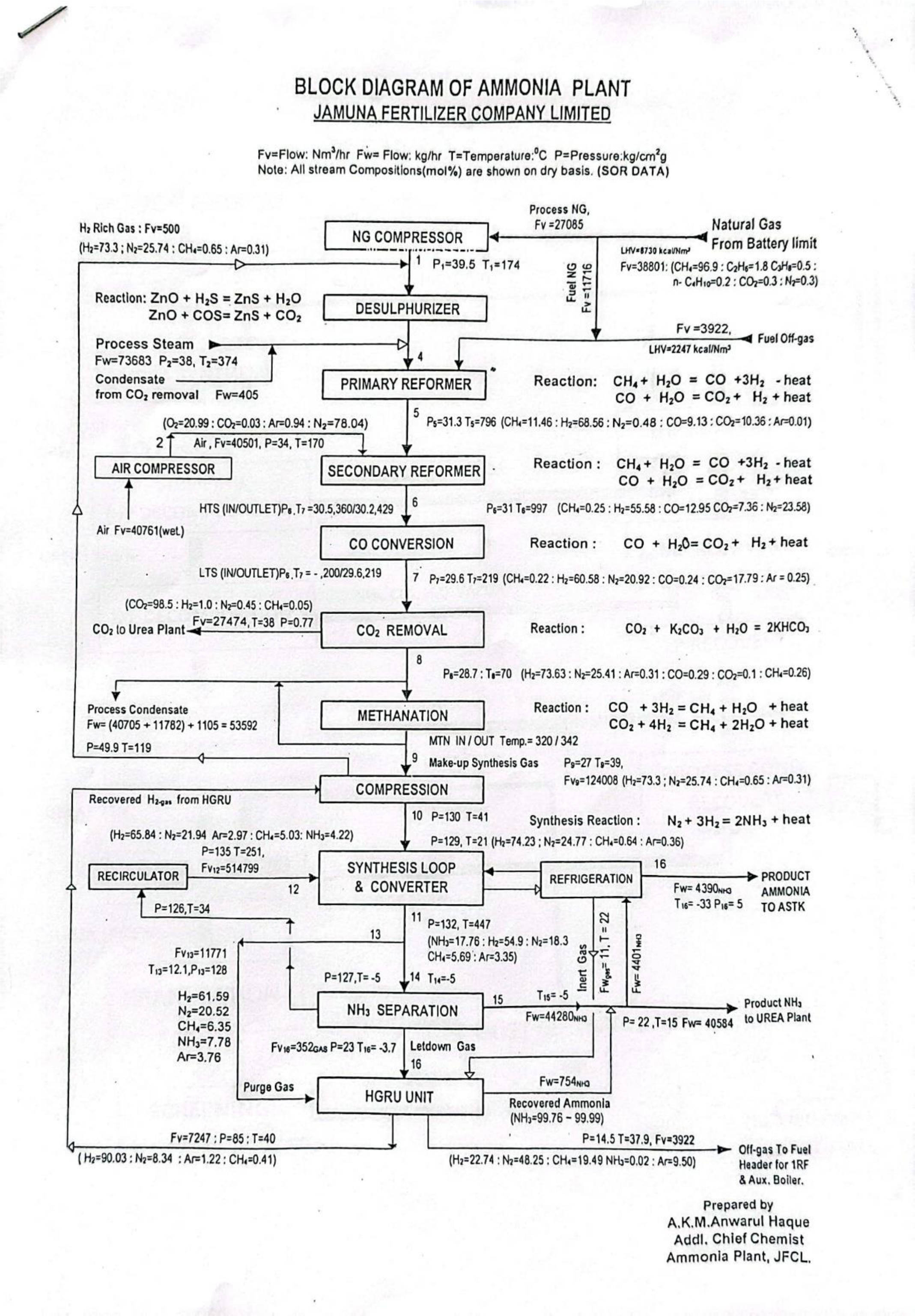
At the Jamuna Fertilizer Plant, urea production involves a two-step process. Initially, ammonia is produced by combining nitrogen and hydrogen, typically derived from natural gas through processes like steam methane reforming and the Haber-Bosch reaction. Subsequently, urea is synthesized by reacting the produced ammonia with carbon dioxide in the Urea Process, resulting in the formation of urea and water. The urea is then processed into a suitable form for use as fertilizer, such as granules, at the Jamuna Fertilizer Plant. This entire production process is vital for supplying nitrogen fertilizer, contributing significantly to the enhancement of crop growth in agriculture. General production process flow diagram is presented below:



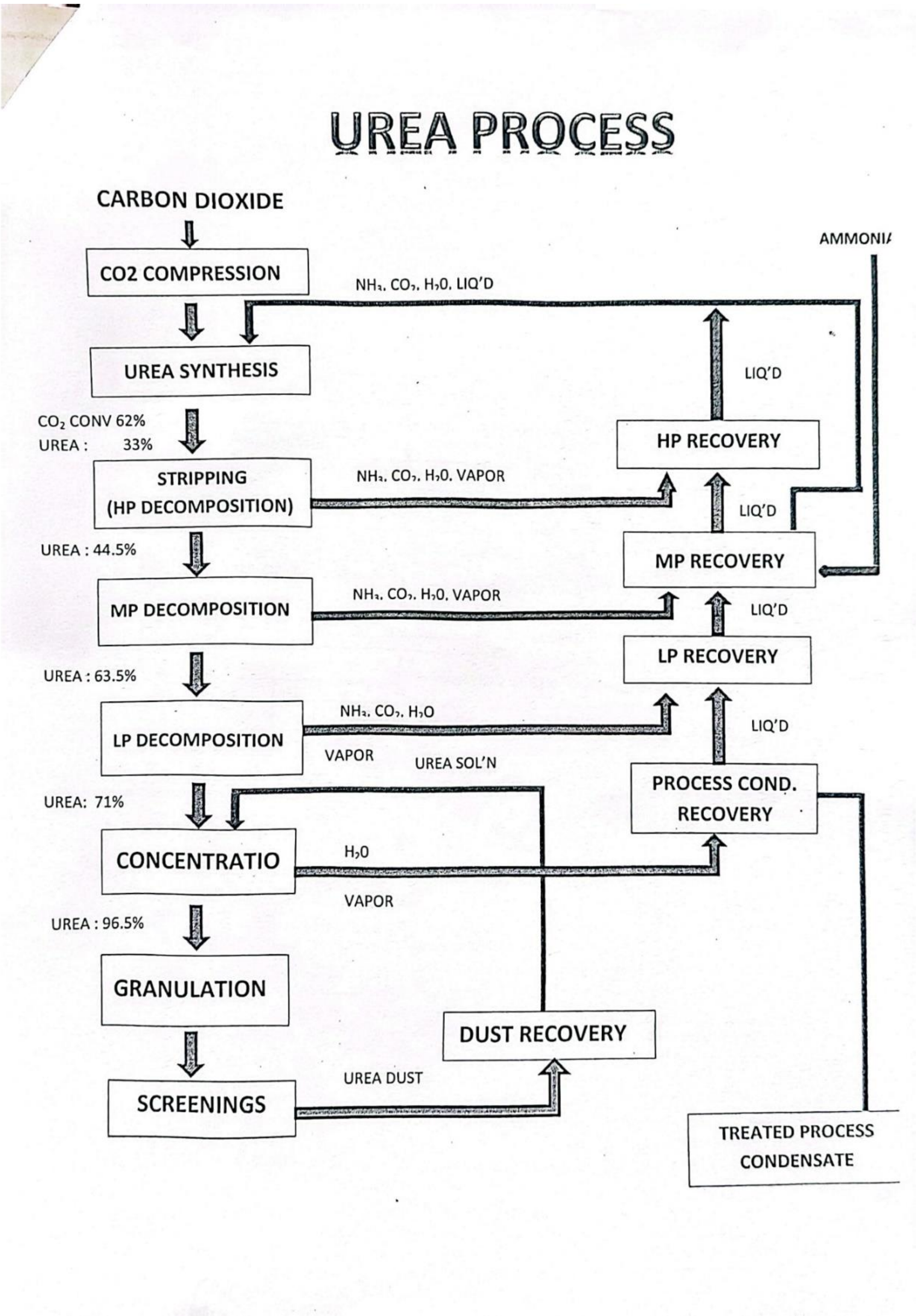
1.6.2. Process flow diagram and major unit operations

There are two units in this plant. One is ammonia production, and another one is urea production. Process flow diagram is presented in the following section.

- Ammonia production process flow diagram



- Urea production process flow diagram



2. Energy and Utility System description

2.1.List of major appliances

Name	Capacity	Quantity
Auxiliary Boilers with superheater & air preheater	65 ton/hr	3
WHR Boilers	200 ton/hr (all together as per design)	1
Steam turbine	8 MW	2
Primary Reformer	27,085 Nm3 of natural gas is required at 100% load and 39 kg/cm2 pressure is required	1
Secondary Reformer	39,000 Nm3 of air is required at 100% load and 34 kg/cm2 pressure is required	1
NH3 converter	355740 MTPY NH3 production capacity	1
Cooling tower	One cooling tower is used for NH3 plant: 17,000 m3/hr water cooling capacity; among 4 sets of pumps, 3 sets of pumps are continuous running and 1 is used for standby at 100% load; all of the pumps design capacity is 6,000 m3/hr. 1 pump is motor driven of 920 kW and other 3 pumps are steam turbine driven. Number of fans is 7 nos with 132 kW motor each. One cooling tower is used for Urea plant: 5,600 m3/hr water cooling capacity; among 3 sets of pumps, 2 sets of pumps are continuous running and 1 is used for standby at 100% load; all of the pumps design capacity is 2,850 m3/hr and driven by motor of 455 kW each. Number of fans is 5 nos with 55 kW motor each. Cooling tower temperature range is from 33ºCto 43ºC as per design	2
Reactor in urea section	561000 MTPY granular urea production capacity	1

Ammonia section

Urea section

Utility section

Auxiliary boiler section

Cooling towers

Instrument air compressors

Gas turbine

Water treatment section

Figure3: Major utilities and equipment at the plant

2.2. Energy metering and measurement system

Meter	Utility (Electricity/Gas)	Location & Area Metered	Monitoring Requirements
Individual gas turbine and steam turbine generators electricity meter	Electricity	Generator control room	Not required
TITAS gas meter	Natural gas	Regulation and metering station at inlet side of the plant	Not required

3. Review of trend of energy consumption with production

There are two types of energy used in the plant: natural gas and electricity. However, electricity is considered the secondary energy source. The primary energy source is natural gas, which is utilized in boilers to generate steam. This steam is then directed to steam turbines to produce electricity. Natural gas serves a dual purpose, with one line supplying as fuel and another providing as raw materials for the process plant. The energy intensity analysis is based on historical data from the fiscal year 2017/18 to 2022/23 and is presented in the following section.

Table 4: Energy Intensity analysis

Year	NG for raw material, 1000m3	NG for fuel, 1000m3	Total NG consumption, 1000m3	Urea production, 1000ton	Energy intensity, GJ/ton	Energy intensity, mcf/ton
2017/18	162314.54	132,802.80	295,117.34	302.41	34.46	34.46
2018/19	60924.15	49,847.03	110,771.18	74.21	52.71	52.71
2019/20	129683.43	106,104.62	235,788.05	210.16	39.62	39.62
2020/21	204571.72	167,376.86	371,948.58	341.61	38.45	38.45
2021/22	170523.87	139,519.53	310,043.40	244.26	44.83	44.83
2022/23	105564.08	86,370.61	191,934.69	151.68	44.69	44.69
Total	**833581.79**	**682,021.45**	**1,515,603.24**	**1324.33**	**40.42**	**40.42**

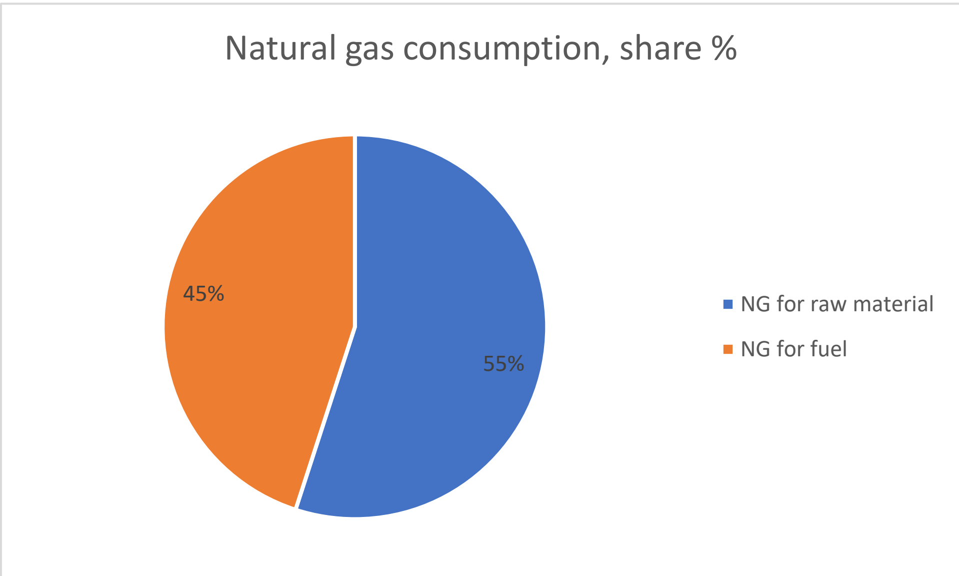


Figure 4: Percentage share of energy consumption

Comments: Around 55% natural gas is used as raw material and rest of the amount is used as fuel.

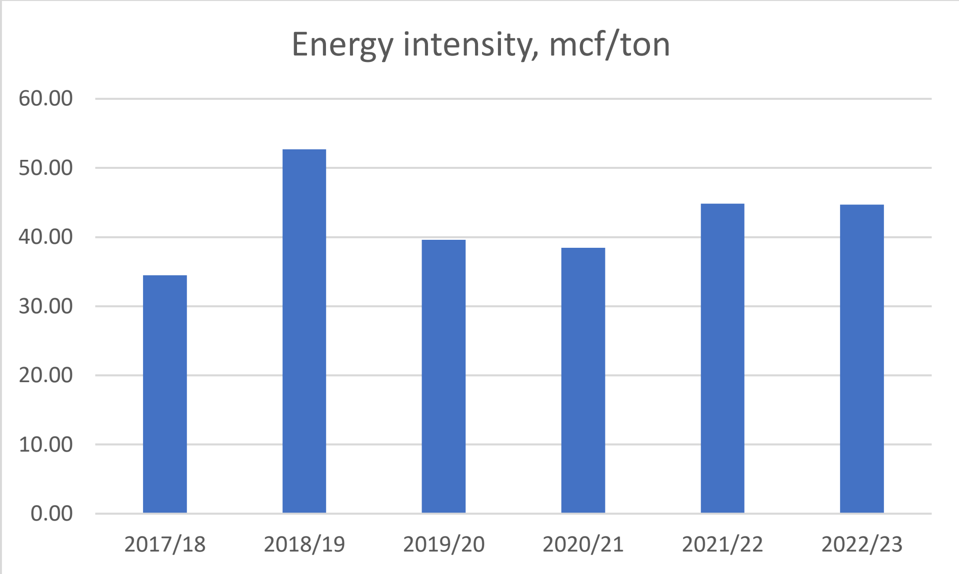
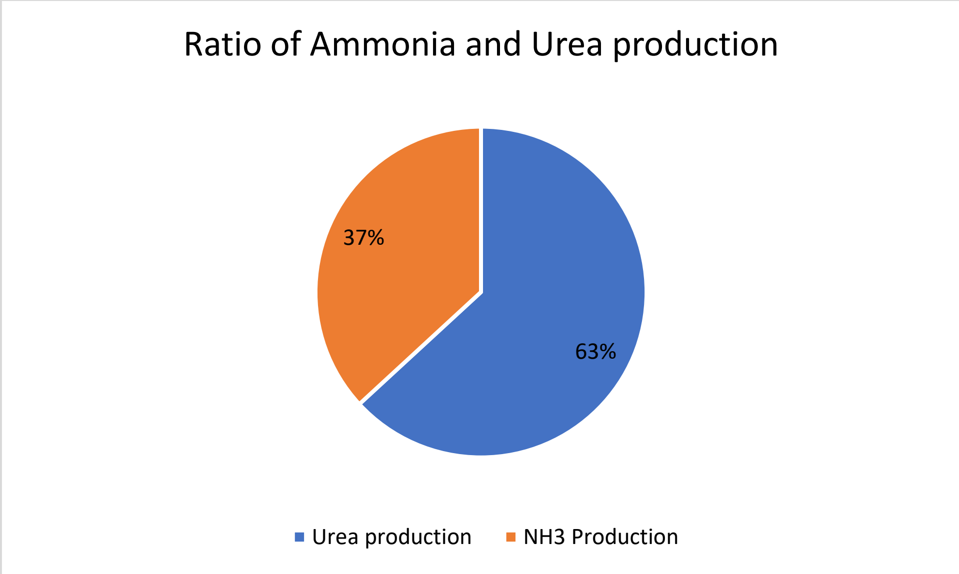


Figure5: Energy intensity analysis

Comments: In the year 2018/19, energy intensity was very high.

Table 5: Ammonia and Urea production ratio

Year	Urea production, 1000ton	NH3 Production, 1000ton	NH3/Urea
Jul-21	302.41	176.76	0.58
Aug-21	74.21	44.08	0.59
Sep-21	210.16	122.19	0.58
Oct-21	341.61	196.38	0.57
Nov-21	244.26	142.13	0.58
Dec-21	151.68	91.44	0.60
Total	**1,324.33**	**772.98**	**0.58**

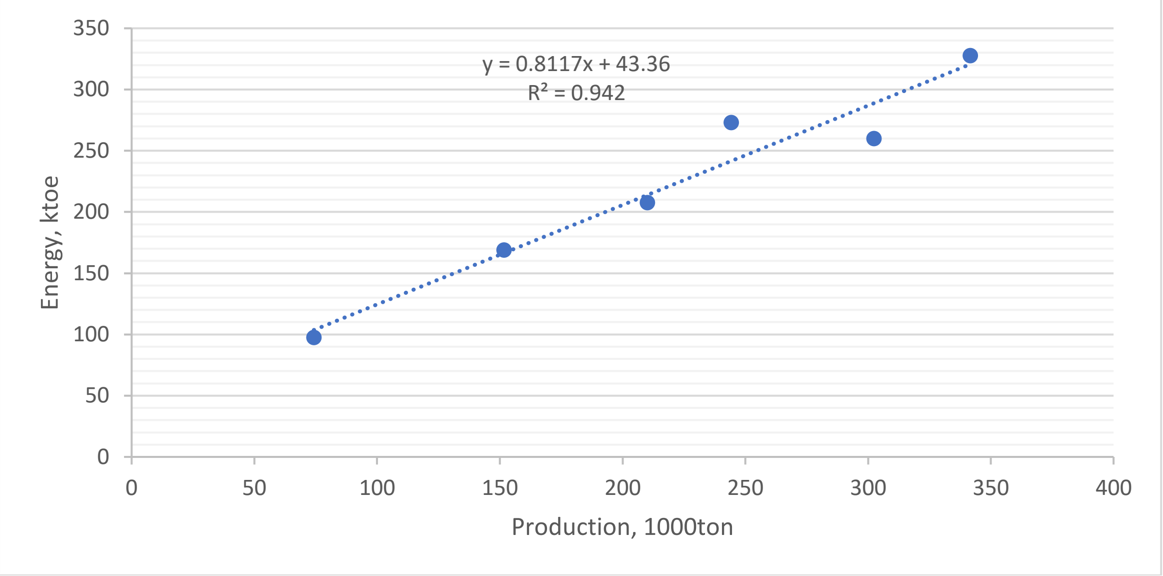


3.1. Production and energy consumption trend (with graph)

Year	Total Energy Consumption (ktoe)	Urea Production (1000ton)	Energy Consumption Per Unit Production (toe/ton)
Jul-21	259.97	302.41	0.86
Aug-21	97.58	74.21	1.31
Sep-21	207.71	210.16	0.99
Oct-21	327.65	341.61	0.96
Nov-21	273.12	244.26	1.12
Dec-21	169.08	151.68	1.11
Total	**1,335.09**	**1,324.33**	**1.01 (Average)**

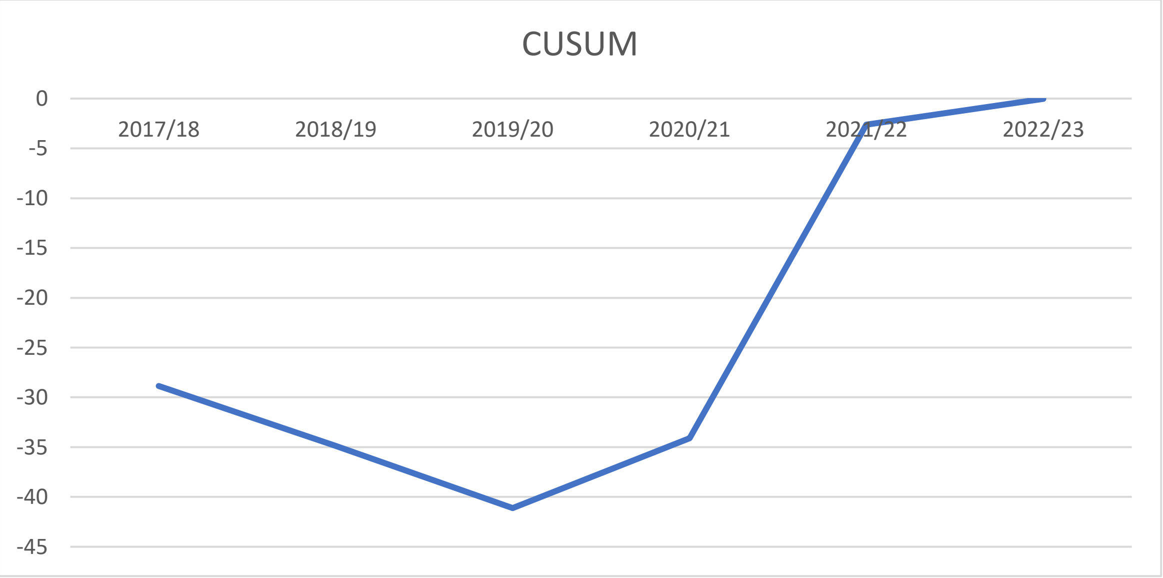
ktoe = kilotonne of oil equivalent (ktoe)

3.2. Regression analysis of energy consumption with production



The R^2 value is very close to 1.00, means data have very much related each other. From this graph, the base energy consumption of the plant is 43.36 ktoe.

3.3. Analysis of CUSUM graph



From the above graph, it is seen that the plant's energy performance is initially better but from the year 2020/21 performance is degraded.

4. Energy efficiency in utility and process systems

4.1. Boiler efficiency assessment

The boiler plant comprises three auxiliary boilers, each with a capacity of 65 tons per hour, and waste heat recovery boilers on the process side. According to the design, the total steam requirement is 300 tons per hour. In the original design, approximately 200 tons per hour of steam is expected from waste heat recovery boilers, while the remaining steam comes from auxiliary boilers. However, the current operational scenario reveals that only around 150 tons per hour is generated from waste heat recovery boilers, and approximately 165 tons per hour is produced from auxiliary boilers. The reduced capacity of waste heat recovery boilers is attributed to a plant utilization factor decrease to around 70%. Another contributing factor is the aging of the plant's equipment, leading to a decline in performance and increased energy consumption, resulting in a rise in steam production to 315 tons per hour.

The steam generated from the boilers is directed into the steam header, which features three main pressure headers at 105 bar, 38 bar, and 3.5 bar. The plant incorporates a condensate recovery system, and exhaust heat is recovered through a superheater, and air preheater.

Boiler efficiency is evaluated based on historical data regarding steam production and gas consumption, detailed in the subsequent section.

Table 6: Performance of the steam production system

Year	NG consumption, m3	Steam production, MT	NG / ton steam, m3/ton	Energy per ton steam, kJ/ton	Efficiency, %
2017/18	20,400,381	245,788	**83**	**3,384,053**	**84**
2018/19	27,873,359	335,824			
2019/20	17,450,385	210,246			
2020/21	22,702,231	273,521			
2021/22	38,839,415	467,945			
2022/23	62,836,784	757,070			
Total	**190,102,554**	**2,290,392**			

4.2. Gas Turbine performance assessment

The plant is equipped with a single gas turbine with a capacity of 4 MW and lacks a waste heat recovery system. The performance of the generator is evaluated based on gas consumption and electricity generation data for the year 2018/19.

Year of analysis	Natural Gas Consumption, m3	Electricity production (kWh)	Generator plant efficiency, %
2018/19	187326	624000	32

4.3. Cooling tower performance assessment

This plant has two separate cooling towers for ammonia and urea section. Bsaed on operatianal data, cooling tower performance has been presented below.

S.N	Parameters	Value	Unit
1	CT supply temp.	41.80	ºC
2	CT return temp.	33.80	ºC
3	Relative Humidity	66.00	ºC
4	Dry bulb temp	35.00	ºC
5	Wet bulb temp	29.30	ºC
6	Range	8.00	ºC
7	Approach	4.50	ºC
8	Effectiveness (at operating condition)	64.00	%

5. ENERGY SAVINGSMEASURES & RECOMMENDATIONES

5.1. Opportunities of Renewable energy use

The plant has opportunities to use rooftop solar power plant. A separate feasibility study will be required for identifying detail calculation**.**

5.2. List of options in terms of No cost/ Low Cost, Medium cost and high investment Cost, Annual Energy & Cost savings, and financial analysis

Table 7: Summary of Energy saving measures/ Recommendations

S.N	Type of measures	Measures	Estimated Energy Savings, TOE/year	CO2 emission reduction, tCO2/year	Estimated monetary Savings, BDT/year	Investment, BDT	Simple Payback Period, years
1	High cost	Waste heat recovery boiler with GT exhaust	1,176.12	2,909.67	22,537,070.72	80,000,000.00	3.55
2	Medium cost	Blowdown heat recovery for preheating makeup water for boilers	410.57	962.79	6,734,860.28	4,000,000.00	0.59

S.N	Type of measures	Measures	Estimated Energy Savings, TOE/year	CO2 emission reduction, tCO2/year	Estimated monetary Savings, BDT/year	Investment, BDT	Simple Payback Period, years
3	Low cost	Steam pipeline insulation	8.33	19.52	151,224.88	146,006.50	0.97
4	Low cost	Steam valves insulation	7.31	17.14	132,723.70	60,000.00	0.45
5	Low cost	Steam traps replacement	27.84	65.28	505,648.92	240,000.00	0.47
6	Low cost	Steam leakage repairing	2.71	6.35	49,171.03	50,000.00	1.02
7	Low cost	Compressed air leakage repairing	8.95	24.57	366,658.90	200,000.00	0.55
8	Low cost	Auxiliary boiler surface insulation repairing	3.52	8.27	64,021.38	58,558.89	0.91

S.N	Type of measures	Measures	Estimated Energy Savings, TOE/year	CO2 emission reduction, tCO2/year	Estimated monetary Savings, BDT/year	Investment, BDT	Simple Payback Period, years
9	Medium cost	Replacement of ordinary ceiling fan by energy efficient (BLDC) ceiling fan	277.75	763.00	11,383,200.00	27,404,000.00	2.41
10	Medium cost	Replacement of mercury, fluorescent and high power CFL by appropriate LED lamps	227.11	624.00	930,794.00	20,405,000.00	2.19
		Total	**2,150.21**	**5,400.58**	**42,855,373.81**	**132,563,565.39**	**3.09**

Details analysis including profitability of the projects is presented below.

Thermal and Mechanical System:

Through our observations, we identified following recommendations which will be considered as potential energy savings projects.

1. Waste heat recovery from exhaust of the Gas Turbine Generator

JFCL Produces Urea, ammonia and 3 types of pressure steam to support Urea and ammonia plant. 3 boilers are used to produce steam, and steam is used to produce electricity for use at plant. One GT (capacity 4 MW) is used to generate electricity. Technical details is presented below table.

Figure 13: Gas turbine of 4MW

SN	Parameters	Values	Unit
1	Gas turbine capacity	4	MW
2	Gas turbine annual running load	40	%
3	Annual operating hours	7920	hrs/year
4	Gas turbine efficiency	32	%
5	Average annual power generation	12672	MWh
6	Exhaust gas temperature	450	ºC

SN	Parameters	Values	Unit
7	Minimum allowable ex. gas temp after HRSG install	120	ºC
8	Specific heat of flue gas	0.25	kcal/kg/ ºC
9	Flue gas flowrate	20000	kg/hr
10	Energy recovered	1.92	MW
11	Steam pressure	6	bar
12	Feed water temp	85	ºC
13	Steam enthalpy	2763	kJ/kg
14	Feed water enthalpy	355.3	kJ/kg
15	HRSG efficiency - assumed	90	%
16	Steam production	2.58	ton/hr
17	Annual energy savings	49,161,816.00	MJ/year
18	Annual natural gas savings	1,408,566.92	SCM/year
19	Annual monetary savings	22,537,070.72	BDT/year
20	Annual CO2 reduction	2,909.67	tCO2/year
21	Investment	80,000,000.00	BDT
22	Simple payback period	3.55	Years
23	ROI	28.17	%
24	NPV	41,386,996.26	BDT
25	IRR	25.19	%

2. Boilers' Blowdown Heat Recovery for Preheating of Boilers' Makeup Water

Currently there is no heat recovery system introduced with the boilers' blowdown system. Cooling water is used to reduce blowdown temperature, and the cooling water is returning to the cooling tower. But this blowdown heat can be utilized to preheat boilers' makeup water. Saving analysis by insulating of the blowdown heat recovery system is presented below.

Table 8: Energy savings by insulating of the blowdown heat recovery system

SN	Parameters	Value	Unit
1	Average Boiler Steam Flowrate	165,000.00	kg/hr
2	Hours of Operation	7920	hr/year
3	Boiler Efficiency	84	%
4	Feed water TDF	150	ppm
5	Maximum allowable TDS	3500	ppm
6	Blowdown %	4.48	%
7	Blowdown rate	7,388.06	kg/hr
8	Blowdown water enthalpy	419	kJ/kg
9	Total blowdown energy	3,095,597.01	kJ/hr
10	Energy can be recovered	2166917.91	kJ/hr

SN	Parameters	Value	Unit
11	Boiler makeup water amount (approximately)	12,960.04	kg/hr
12	Annual operating hours	7920	hr/year
13	Annual fuel savings	420,928.77	m3/hour
14	Annual CO2 emission reduction	962.79	tCO2/year
15	Annual monetary savings	6,734,860.28	BDT/year
16	Investment	4,000,000.00	BDT
17	Simple payback period	0.59	Years
18	ROI	168.37	%
19	NPV	19,580,842.20	BDT
20	IRR	167.13	%

3. Insulation of the damaged or uninsulated steam pipe

The audit team identified damaged and uninsulated steam pipes, capturing thermal images of the exposed surfaces. Based on these observations, an analysis is presented below.

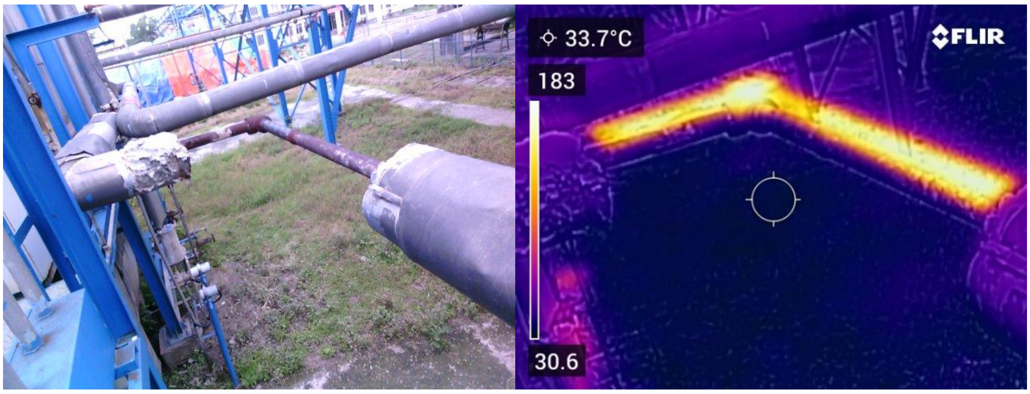


Figure 14: Thermal images of uninsulated steam pipe

Table 9: Energy savings by insulating of the bare steam pipe

S.N	Parameters	Value	Unit
1	Bare surface temp	160	ºC
2	Ambient temperature	30	ºC
3	Heat loss	2,145	kcal/hr/m2
4	After insulation surface temperature	60	ºC
5	Heat loss	345	kcal/hr/m2
6	Hourly energy savings per m2	1,800	kcal/hr/m2
7	Bare surface area	5.84	m2
8	Energy savings per hour	10,512	kcal/hr
9	Operational hours	7,920	hr/year

S.N	Parameters	Value	Unit
10	Annual energy savings	83,258,746	kcal/year
11	Boiler efficiency	84	%
12	LHV of natural gas	8,809	kcal/m3
13	Equivalent fuel savings	9,452	m3/year
14	Annual CO2 reduction	19.52	tCO2/year
15	Annual monetary savings	151,225	BDT/year
16	Investment	146,006	BDT
17	Simple payback period	1.0	Year
18	ROI	103.57	%
19	NPV	383,478.87	BDT
20	IRR	100.37	%

4. <u>Insulation of the damaged or uninsulated steam valves</u>

The audit team identified uninsulated steam valves, capturing thermal images of the exposed surfaces. Based on these observations, an analysis is presented below. The audit team collected some uninsulated valves' temperature profile through thermal images as sample basis and potential savings are presented below.

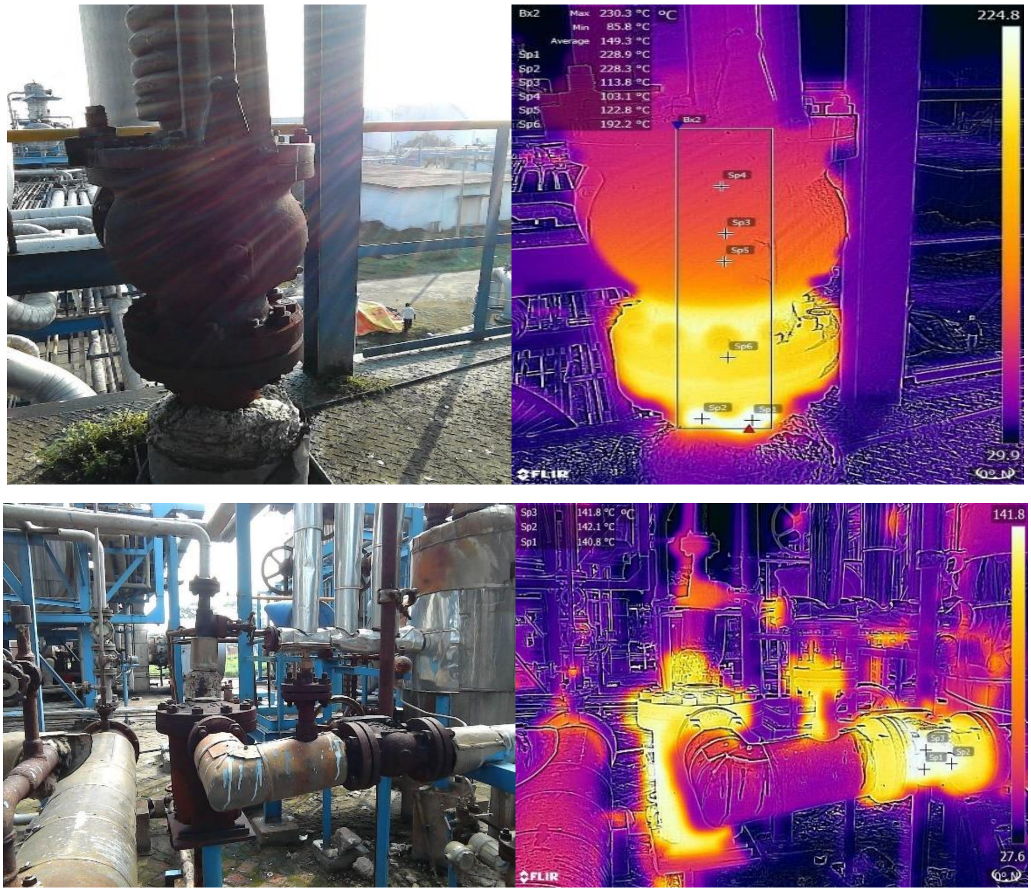


Figure 815: Thermal images of uninsulated steam valves

Area of a valve				
Valve size	16	inch	1	Nos
Area of a valve	5.295	m2		
Valve size	4	inch	1	Nos
Area of a valve	0.563	m2		

Table 10: Energy savings by insulating of the bare steam valves

S.N	Parameters	Value	Unit
1	Bare surface temp	150	ºC
2	Ambient temperature	30	ºC
3	Heat loss	1,920	kcal/hr/m2
4	After insulation surface temperature	60	ºC
5	Heat loss	345	kcal/hr/m2
6	Hourly energy savings per m2	1,575	kcal/hr/m2
7	Bare surface area	5.858	m2
8	Energy savings per hour	9,226	kcal/hr
9	Operational hours	7,920	hr/year
10	Annual energy savings	73,072,692	kcal/year
11	Boiler efficiency	84	%
12	LHV of natural gas	8,809	kcal/m3
13	Equivalent fuel savings	8,295	m3/year
14	Annual CO2 reduction	17.14	tCO2/year
15	Annual monetary savings	132,724	BDT/year
16	Investment	60,000	BDT
17	Simple payback period	0.45	Year
18	ROI	221.21	%
19	NPV	404,706.99	BDT
20	IRR	220.55	%

5. Repair steam traps

The audit team identified some of the steam traps are not functioning properly. Based on the observations, an analysis is presented below. The audit team collected data on malfunctioning steam traps as a sample basis and potential savings are presented below.

Figure9: Steam traps

Table 11: Energy savings by repairing steam traps

S.N	Parameters	Value	Unit
1	Steam trap size, Dia	0.75	inch
2	Orifice size, Dia	0.0938	inch
3	Steam pressure	3.50	kg/cm2
4	Steam pressure (absolute)	65.25	psia
5	Steam flow through faulty trap	6.31	kg/hr
6	Number of traps	12.00	Nos.
7	Total steam loss	75.67	kg/hr
8	Energy savings per hour	45,399.76	kcal/hr
9	Operational hours	6,132.00	hr/year
10	Annual energy savings	278,391,334.74	kcal/year
11	Boiler efficiency	84	%
12	LHV of natural gas	8,809.00	kcal/m3
13	Equivalent fuel savings	31,603.06	m3/year
14	Annual CO2 reduction	65.28	tCO2/year
15	Annual monetary savings	505,648.92	BDT/year
16	Investment	240,000.00	BDT
17	Simple payback period	0.47	Year
18	ROI	210.69	%
19	NPV	1,530,434.27	BDT
20	IRR	209.95	%

6. Repair steam leakages

The audit team identified many steam leakages by walk through. Based on the physical and measured data, an analysis is presented below. The audit team collected data on steam leakages as a sample basis and potential savings are presented below.

Figure 10: Steam leakages

Table 12: Energy savings by repairing steam leakages

S.N	Parameters	Value	Unit
1	Hole size, Dia	0.0200	inch
2	Steam pressure	39.00	kg/cm2
3	Steam pressure (absolute)	580.00	psia
4	Steam flow through the hole	2.55	kg/hr
5	Number of holes	2.00	Nos.
6	Total steam loss	5.10	kg/hr
7	Energy savings per hour	3,418.15	kcal/hr
8	Operational hours	7,920.00	hr/year
9	Annual energy savings	27,071,727.30	kcal/year
10	Boiler efficiency	84	%
11	LHV of natural gas	8,809.00	kcal/m3
12	Equivalent fuel savings	3,073.19	m3/year
13	Annual CO2 reduction	6.35	tCO2/year
14	Annual monetary savings	49,171.03	BDT/year
15	Investment	50,000.00	BDT
16	Simple payback period	1.02	Year
18	ROI	98.34	%
19	NPV	122,163.09	BDT
20	IRR	94.84	%

7. <u>Repair compressed air leakages</u>

During the field visit, the audit team identified numerous compressed air leakages throughout the facility, noting these by both physical inspection and measurement techniques. Using sample data on leak size, operating pressure, and system runtime, the team estimated the energy losses and potential savings associated with these leaks. The analysis suggests that by repairing the detected leaks, the facility could significantly reduce energy consumption, lower operational costs, and decrease carbon emissions. A summary of potential savings is presented, highlighting the volume of air lost, energy and cost impacts, and overall benefits of improved system efficiency.

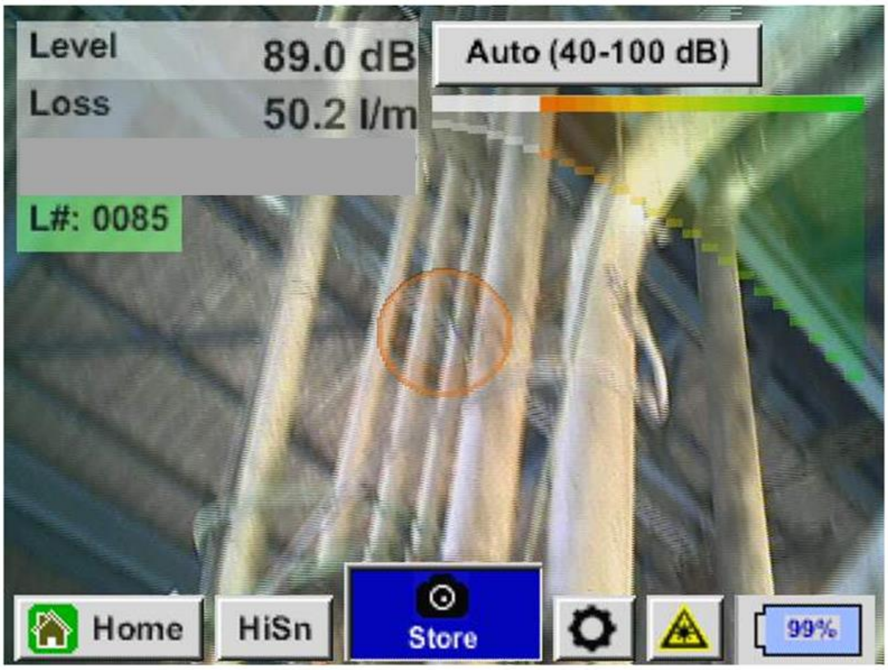


Figure 11: Compressed air leakage; zone – instrument air compressor room

Table 13: Energy savings by repairing compressed air leakages

S.N	Parameters	Value	Unit
1	Number of leakages	6	Nos.
2	Total leakage rate	28.93	m3/hr
3	Operational hours	7,920.00	hr/year
4	Specific energy consumption	0.16	kWh/m3
5	Total energy loss (which can be saved)	36,665.89	kWh/year
6	Annual CO2 reduction	24.57	tCO2/year
7	Annual monetary savings	366,658.90	BDT/year
8	Investment	200,000.00	BDT

S.N	Parameters	Value	Unit
9	Simple payback period	0.55	Year
10	ROI	183.33	%
11	NPV	1,083,786.94	BDT
12	IRR	182.31	%

8. <u>Repair boiler surface insulation</u>

The audit team found that the boiler surface insulation is generally in good condition, with only a few hot spots identified. An analysis of these hot spots is presented below. The plant has also scheduled maintenance to address these areas and improve insulation effectiveness. Detailed findings and recommendations for the boiler surface are outlined in the following analysis.

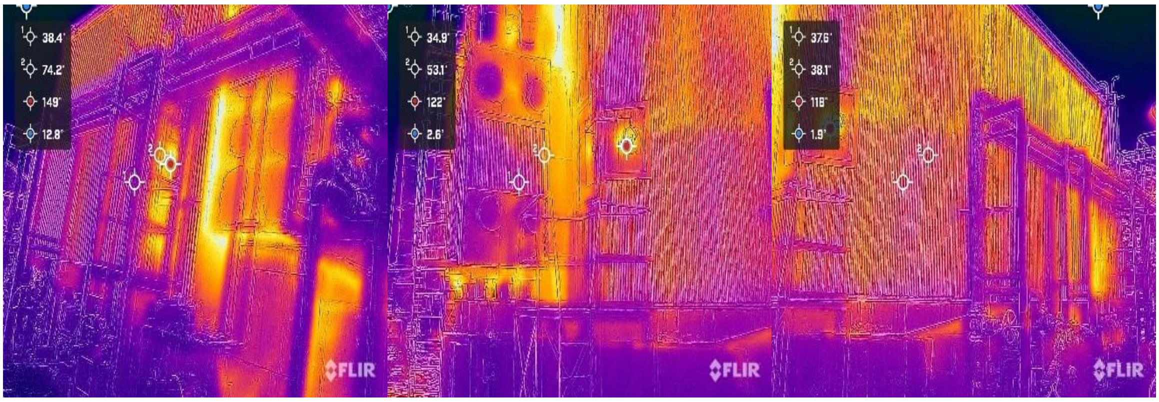


Figure 12: Good thermal insulation of the other surfaces of the auxiliary boilers

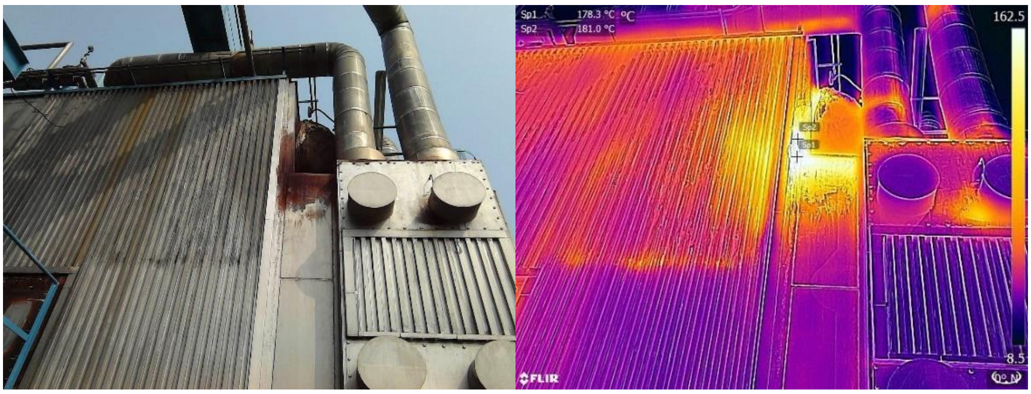


Figure 16: Hot spots of the auxiliary boilers

Saving after insulation of the hot surfaces of the auxiliary boilers is presented below.

Figure 17: Savings through repairing the insulation of the hot zones of the boiler surface

S.N	Parameters	Value	Unit
1	Hot surface temp	180	deg.C
2	Ambient temperature	30	deg.C
3	Heat loss	2,625	kcal/hr/m2
4	After insulation surface temperature	60	deg.C
5	Heat loss	345	kcal/hr/m2
6	Hourly energy savings per m2	2,280	kcal/hr/m2
7	Hot surface area	1.95	m2
8	Energy savings per hour	4,450	kcal/hr
9	Operational hours	7,920	hr/year
10	Annual energy savings	35,247,769	kcal/year
11	Boiler efficiency	84	%
12	LHV of natural gas	8,809	kcal/m3
13	Equivalent fuel savings	4,001	m3/year
14	Annual CO2 reduction	8.27	tCO2/year
15	Annual monetary savings	64,021	BDT/year
16	Investment	58,559	BDT
17	Simple payback period	0.9	Year
18	ROI	109.33	%
19	NPV	165,599.87	BDT
20	IRR	106.41	%

Comments on the identified ECMs: To accurately determine the total energy loss and potential savings from all identified opportunities, a comprehensive assessment will be necessary. This evaluation will involve a detailed examination of each area where energy savings have been identified, including compressed air leaks, steam leakages, and insulation hot spots, among others. Each opportunity will need to be assessed for factors such as system pressure, leakage size, insulation effectiveness, and operational hours. By collecting precise data for each area, the assessment will allow for accurate calculations of current energy losses, associated costs, and potential environmental benefits from implementing corrective actions. This holistic approach will enable the facility to prioritize high-impact improvements, maximize energy savings, reduce operational costs, and contribute to overall energy efficiency and sustainability goals.

Electrical System:

1. Energy efficiency improvement options- 01: replacement of ordinary ceiling fan by energy efficient (BLDC) ceiling fan

The facility has about 300 pieces of ceiling fan in the production side and 3,916 pieces of ceiling fan in residential areas (other than production area). The fans run average 15hours per day and about 300 day per year.
Replacement of existing total 4,216 pieces of ordinary (100W) ceiling fan by energy efficient ceiling fan (40W), will save 1,138,320kWh (about 60%) of electricity each year and reduce CO2 emission by 763tons per year. The simple payback period is only 2.41 years.

PARTICULARS	PARAMETER	
Ceiling fan rating- existing	100	watt
Ceiling fan rating- proposed	40	watt
Power saving	60	watt
Operational time	300	day/year
	15	h/day
	4,500	h/year
Energy saving/year (per fan)	270	kWh
Number of ceiling fan	4,216	pcs
Total energy saving/year	1,138,320	kWh
Electricity cost	10	BDT/kWh
Cost of saved energy	11,383,200	BDT
Cost of energy efficient fan	6,500	BDT/pcs
Total cost of fans	27,404,000	BDT
Simple payback period	2.41	years
Grid emission factor	670	gCO2/kWh
CO2emission reduction	763	ton/year
ROI	41.5	%

2. Energy efficiency improvement options- 02: replacement of mercury, fluorescent and high power CFL by appropriate LED lamps

In this production facility about 2,130nos of T8 (4feet/40W) fluorescent lamps are running with traditional magnetic ballast. About 130nos of high power CFL (65W) are used as streetlight in residential areas. About 90 nos of mercury lamp (400W) are used as streetlight, 146 nos as yard light, 100 nos as boundary light and 30 nos as bulk area go-down light. About 515nos of mercury lamp (250W) are used in production areas and warehouse areas.

Replacement of existing 366 pieces of mercury lamps (400W) by LED flood lamps (150W) 535 pieces of mercury lamps (250W) by LED flood lamps (100W), 65 pieces of high power CFL lamps (65W) by LED lamps (30W) and 2,130 pieces of fluorescent lamps (40W) by LED (T8) lamps (23W) will save 930,794kWh of electricity each year and reduce CO2 emission by 624tons per year. The simple payback period is only 2.19 years.

Summary

PARTICULARS	PARAMETER	
Total energy saving/year	930,794	kWh
Electricity cost	10	BDT/kWh
Cost of saved energy	9,307,938	BDT
Total cost of LED lamps (all)	20,405,000	BDT
Simple payback period	2.19	years
Grid emission factor	670	gCO2/kWh
CO2emission reduction	624	ton/year
ROI	45.7	%

- Mercury lamp – 400W

PARTICULARS	PARAMETER	
Mercury lamp- existing	400	watt
LED lamp- proposed (150 lm/W)	150	watt
Power saving	250	watt
Operational time	365	day/year
	12	h/day
	4,380	h/year
Energy saving/year (per lamp)	1,095	kWh
Number of LED lamps	366	pcs
Total energy saving/year	400,770	kWh
Electricity cost	10	BDT/kWh
Cost of saved energy	4,007,700	BDT
Cost of energy efficient LED lamps	20,000	BDT/pcs
Total cost of LED lamps	7,320,000	BDT
Simple payback period	1.83	years
Grid emission factor	670	gCO2/kWh
CO2emission reduction	269	ton/year

- Mercury lamp – 250W

PARTICULARS	PARAMETER	
Mercury lamp- existing	250	watt
LED lamp- proposed (150 lm/W)	100	watt
Power saving	150	watt
Operational time	365	day/year
	12	h/day

	4,380	h/year
Energy saving/year (per lamp)	657	kWh
Number of LED lamps	535	pcs
Total energy saving/year	351,495	kWh
Electricity cost	10	BDT/kWh
Cost of saved energy	3,514,950	BDT
Cost of energy efficient LED lamps	18,000	BDT/pcs
Total cost of LED lamps	9,630,000	BDT
Simple payback period	2.74	years
Grid emission factor	670	gCO2/kWh
CO2emission reduction	236	ton/year

- Fluorescent lamp – 40W

PARTICULARS	**PARAMETER**	
Fluorescent lamp- existing	40	watt
LED lamp (T8)- proposed (100 lm/W)	23	watt
Power saving	17	watt
Operational time	365	day/year
	12	h/day
	4,380	h/year
Energy saving/year (per lamp)	74	kWh
Number of LED lamps	2,130	pcs
Total energy saving/year	158,600	kWh
Electricity cost	10	BDT/kWh
Cost of saved energy	1,585,998	BDT
Cost of energy efficient LED lamps	1,500	BDT/pcs
Total cost of LED lamps	3,195,000	BDT
Simple payback period	2.01	years
Grid emission factor	670	gCO2/kWh
CO2emission reduction	106	ton/year

Compact fluorescent lamp – 65W

PARTICULARS	**PARAMETER**	
Compact fluorescent lamp- existing	65	watt
LED lamp- proposed (100 lm/W)	30	watt
Power saving	35	watt
Operational time	365	day/year
	12	h/day
	4,380	h/year
Energy saving/year (per lamp)	153	kWh

Number of LED lamps	130	pcs
Total energy saving/year	19,929	kWh
Electricity cost	10	BDT/kWh
Cost of saved energy	199,290	BDT
Cost of energy efficient LED lamps	2,000	BDT/pcs
Total cost of LED lamps	260,000	BDT
Simple payback period	1.30	years
Grid emission factor	670	gCO2/kWh
CO2emission reduction	13	ton/year

5.3. Implementation Strategy for Energy Savings Projects

The successful implementation of the energy savings project at Jamuna Fertilizer Company Limited is an independent initiative, contingent upon the active involvement and commitment of the company's personnel to realize financial benefits. The following steps are proposed to facilitate a seamless implementation process:

1. Prioritize Recommendations:

- Classify Projects by Impact: Identify high, medium, and low-impact projects based on energy savings potential.
- Cost-Benefit Analysis: Evaluate the cost and payback period for each recommendation.
- Ease of Implementation: Consider the complexity of each project, including technical feasibility, workforce needs, and potential disruption to operations.
- Compliance & Standards: Ensure that the projects align with local regulations, energy standards, and sustainability goals.

2. Develop a Detailed Action Plan

- Set Targets: Define specific energy reduction targets (e.g., kWh reduction, percentage decrease in energy consumption).
- Timeline & Phases: Break down the projects into phases (short-term, medium-term, long-term), with clear deadlines for each phase.
- Assign Responsibilities: Identify project leaders and teams responsible for implementation.
- Identify Resources: Determine the resources required for each project, such as capital investments, equipment, and personnel.

3. Ensure Funding & Approvals

- Budgeting: Allocate budget for projects based on priority and projected savings.

- Seek Funding: Explore available financing options like government incentives, green bonds, or internal company budgets.
- Management Buy-In: Present the benefits of the energy-saving measures to senior management to gain approval.

4. Procurement & Vendor Selection

- Identify Vendors: Find and vet suppliers for energy-efficient equipment and technologies.
- Request Proposals: Issue requests for proposals (RFPs) for key projects, ensuring competitive pricing.
- Negotiate Contracts: Focus on long-term partnerships and warranties to ensure sustainable savings.

5. Monitor and Measure Implementation

- Install Monitoring Systems: Use smart meters and energy management systems to track progress in real time.
- Set Key Performance Indicators (KPIs): Define KPIs such as energy savings, ROI, and greenhouse gas (GHG) reductions.
- Regular Reviews: Schedule periodic reviews to assess progress, address any challenges, and adjust the strategy if needed.

6. Training & Capacity Building

- Employee Training: Train staff on new energy-efficient systems and technologies.
- Awareness Programs: Encourage energy-conscious behaviour across the workforce (turning off equipment, reducing waste, etc.).

7. Engage Stakeholders

- Internal Communication: Regularly update internal stakeholders on the progress and success of energy-saving projects.

- External Communication: If applicable, communicate energy savings and sustainability achievements to clients, partners, and regulatory bodies.

8. Measure Success & Continuous Improvement

- Audit and Review: Conduct periodic internal audits to ensure the measures are delivering the projected savings.

- Report Results: Provide detailed reports on savings achieved, ROI, and emissions reductions.

- Adjust Strategy: Based on ongoing reviews, refine and optimize the strategy for continuous improvement.

This approach will ensure that energy savings projects are aligned with organizational goals, implemented efficiently, and monitored for long-term success.

The proposed implementation strategy not only prioritizes knowledge dissemination but also aims to motivate key stakeholders at various organizational levels. By building awareness and garnering support, the energy savings project can be seamlessly integrated into the operational framework of Jamuna Fertilizer Company Limited. The subsequent energy audit report will serve as a crucial reference point for financial analysis, including Return on Investment (ROI), Simple Payback Period, and Cost-Effectiveness Analysis, ensuring a comprehensive evaluation of the project's success.

6. Conclusions

1. The overall energy intensity of the plant is 40.42 mcf/ton of urea, based on energy and production data spanning from FY2017/18 to 2022/23. Although some energy-saving measures have been implemented, there remain numerous opportunities for enhancing energy efficiency.

2. The energy efficiency of the auxiliary boiler plant stands at approximately 84%. The plant is equipped with a condensate recovery system, superheater, and air preheater. However, improvements are needed, especially in insulating valves, flanges, and steam piping. Also steam leakage is found in several areas which indicates energy loss. Repairing steam leakage can save significant amount of energy. As well as found many steam traps are malfunctioning indicates energy loss. A comprehensive assessment will be necessary to determine the total energy loss associated with uninsulated steam pipes, valves and flanges, steam leakages and malfunctioning of steam traps. Notably, the recovery of flash steam from continuous blow-down is being effectively implemented. But blowdown heat is not recovered. This continuous blowdown heat can be recovered to preheat makeup water of the boilers. Boilers surface insulation is well but some hot spots were identified.

3. The gas turbine demonstrates an efficiency of around 32%. Consideration could be given to installing an exhaust gas boiler to recover waste heat from the gas turbine exhaust, thereby boosting overall efficiency.

4. The plant's management actively monitors the air-fuel ratio and optimizes it for maximum efficiency across boilers, reformers, and other appliances, following the manufacturer's recommendations. The audit team found around 3.5% of oxygen at flue gas of the auxiliary boilers which is good enough.

5. The total required steam from the Waste Heat Recovery (WHR) boilers is designed to be around 200 tons per hour. However, the current steam production from the WHR boilers does not meet the design conditions. This discrepancy is likely due to scaling or fouling occurring in the heat exchange tubes. To rectify this issue and ensure optimal heat transfer and system efficiency, it is imperative to implement a heat exchanger cleaning program immediately.

6. Many compressed air leakages were found. Repair all the compressed air leakages to prevent energy wastage and optimize the performance of the compressed air system

7. The plant is using many inefficient lights which can be replaced by LED lights. As well as inefficient fans are being used in the plant which can be replaced by energy efficient BLDC fans.

8. There is a need for improvement in the plant's housekeeping practices. Addressing and enhancing these practices can contribute to a more efficient and organized operational environment.

7. Annexures

7.1. Parameters used in the Calculations

S.N	Parameters used in calculation	Value	Unit	Source
1	LHV of NG	36.82162	MJ/Nm3	JFCL
	1 kWh of Electricity	0.000244	toe	SREDA National Energy Balance
	1 kcal	4.18	kJ	
2	NG tariff	16	BDT/SCM	Fertilizer plant gas tariff
3	CO2 emission factor for natural gas	2.065692882	kgCO2/SCM	2006 IPCC Guidelines on National GHG Inventories
	CO2 emission factor for grid electricity	0.67	kgCO2/kWh	http://www.doe.gov.bd/site /notices/059ddf35-53d3-49a7-8ce6-175320cd59f1 /Grid-Emission-Factor(GEF)-of-Bangladesh
4	Discount Factor	12%		
5	Inflation Factor	7%		
6	Actual Discount Factor	5%		

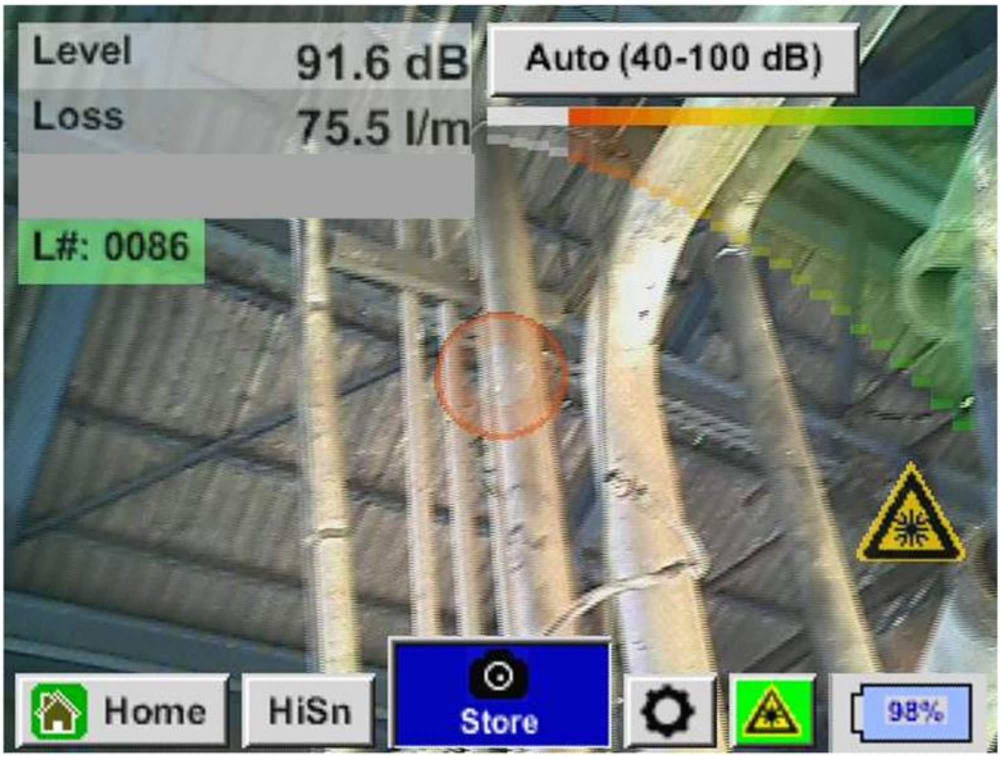
7.2. List of instruments

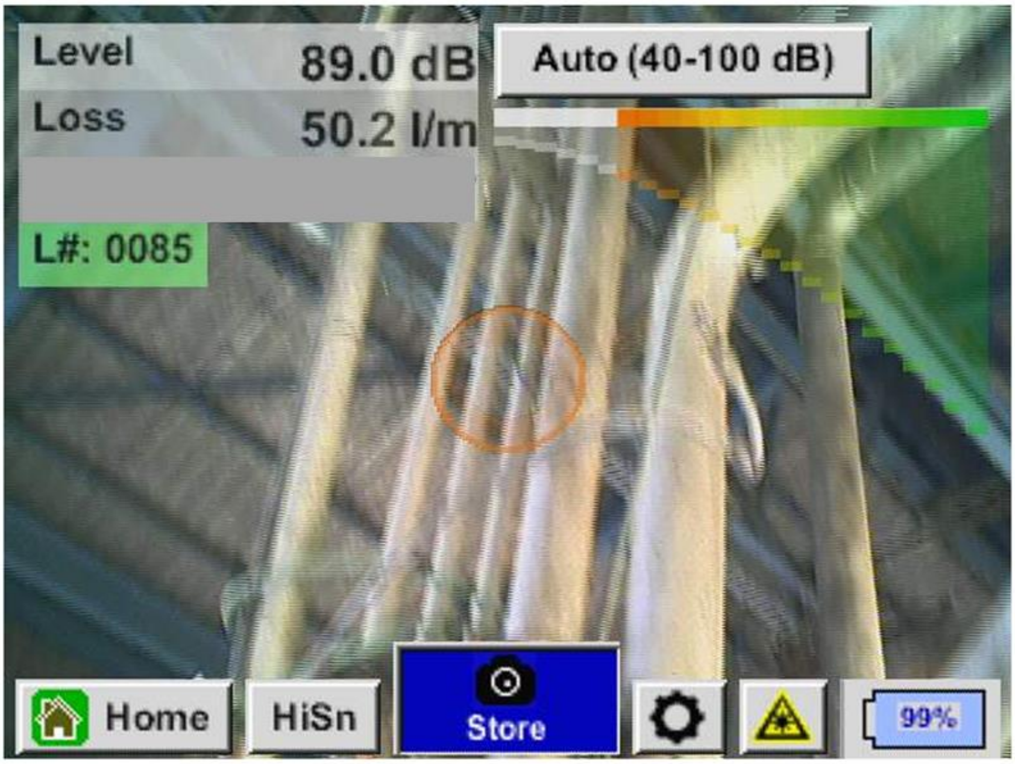
1. Flue gas analyser – Brand – Fluke & Model – 320
2. Thermal Image Camera – Brand – FLIR & Model – C5
3. Power logger – Brand – HIOKI
4. Ultrasonic Flow Meter – Brand – Omega
5. Acoustic Camera for Compressed Air Leak Detection – Brand – CS Instruments

7.3. Flue gas analysis data

- Flue gas analysis data of the auxiliary boilers

- Compressed air leak detection





Annex B

Energy Audit Reports of CUFL

Energy Audit Report

of

Chittagong Urea Fertilizer Company Limited

Rangadia, Anwara, Chittagong, Bangladesh

Prepared by

AUDITOR TEAM

SUSTAINABLE AND RENEWABLE ENERGY DEVELOPMENT AUTHORITY

December 2023

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ACKNOWLEDGEMENT

The Sustainable and Renewable Energy Development Authority (SREDA) extends its heartfelt appreciation to the senior management team and other officials of Chittagong Urea Fertilizer Limited for granting us the privilege to conduct an energy audit at their facility. The audit team would like to acknowledge the technical staff for their invaluable assistance in executing the audit. We extend our gratitude to them for promptly providing the necessary information that greatly facilitated the energy audit process. We also express our thanks for the engaging discussions, generous support, and the enjoyable moments shared during our visits to Chittagong Urea Fertilizer Limited. The collaborative spirit and cooperation demonstrated by the entire team have contributed significantly to the success of this audit.

LIMITATIONS

The services performed by the team members are conducted in a manner consistent with the level of care and skill generally exercised by members of the engineering and consulting profession. The report may not exhaustively cover an investigation of all possible environmental and energy conservation aspects and circumstances that may exist. However, efforts have been made to discover all meaningful areas under the stipulated time available. The technical data sheets are studied and some data is taken from the sheet which may differ in practical condition. Some data could not be collected like from large MV motors and fans due to unavailability of appropriate mechanism and tools. The flow meter results have high uncertainty as the actual pipe thickness cannot be measured due to scaling. The efficiency of auxiliary boiler could not be measured. Available data regarding pricing for investment analysis is taken into consideration which may differ as well.

DISCLAIMER

This Energy Audit Report has been prepared by audit team of Sustainable and Renewable Energy Development Authority (SREDA) and The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The purpose of this report is to assess and analyze the energy consumption and efficiency of the Chittagong Urea Fertilizer Factory based on the information gathered during the audit process.

This energy audit is conducted in accordance with industry standards and best practices. The assessment includes a review of the facilities of Ammonia plant, Urea Plant, Utility Section, Water Treatment Process, Conveyor System, and the Effluent Treatment Plant. The audit team analyzes the energy consumption patterns of the entire facility. The findings and recommendations provided in this report are based on the information available at the time of the audit. It is important to note that the accuracy and effectiveness of the audit are contingent upon the data provided by the client and the conditions observed during the site visit. Factors such as changes in occupancy, equipment usage, and external influences can impact the actual energy performance of the facility. The recommendations outlined in this report are based on current conditions and assumptions. Any changes to the facility, equipment, or operational practices may affect the accuracy and applicability of these recommendations.

The Sustainable and Renewable Energy Development Authority (SREDA), GIZ and its representatives are not liable for any direct, indirect, incidental, consequential, or special damages, losses or expenses arising out of the use of or reliance upon the information provided in this report.

The Chittagong Urea Fertilizer Company is responsible for implementing the recommendations outlined in this report. SREDA or the energy audit team is not responsible for the client's decisions or actions taken as a result of this audit. This report is provided in good faith, and every effort has been made to ensure its accuracy.

N. B. If you have any queries regarding this report, please contact us within three months from the issuing date of this report.

ABBREVIATION

AC	Alternating Current
CO	Carbon Mono Oxide
CO2	Carbon Dioxide
CUFL	Chittagong Urea Fertilizer Limited
DC	Direct Current
DG	Diesel Generator
ECM	Energy Conservation Measures
EMS	Energy Management System
GCV	Gross Calorific Value
GEG	Gas Engine Generator
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GJ	Gigajoule
HC	Hydrocarbons
IRR	Internal Rate of Return
Kg	Kilogram
KJ	Kilojoule
kW	Kilowatt
kWh	Kilowatt Hour
m3	Cubic Meter
MJ	Mega-joule
MT	Metric Ton
NG	Natural Gas
NPV	Net Present Value
O&M	Operations and Maintenance
PF	Power Factor
PLC	Programmable Logic Controller
RH	Relative Humidity
SEC	Specific Energy Consumption
SREDA	Sustainable and Renewable Energy Development Authority
VFD	Variable Frequency Drive
WHR	Waste Heat Recovery

CONVERSION FACTORS

1 kWh of electricity	3.60	MJ
1m³ Natural Gas	35.27	MJ
1Litre of Diesel	36.00	MJ
1ft³	0.0283	m³
Specific heat of air	0.25	kcal/kg °C
Specific Heat of Flue Gas	0.23	kcal/kg °C
1cal	4.187	J
1 SCM of Natural Gas emits	2.04	kg of CO2
1 kWh of Grid Electricity emits	0.67	kg of CO2
Energy Tariff		
Gas (Captive Power)	16	BDT/m³
Gas (Industry)	16	BDT/m³
Electricity (As per STG production of CUFL)	8.80	BDT/ kWh
Exchange Rate		
1 USD	115	BDT

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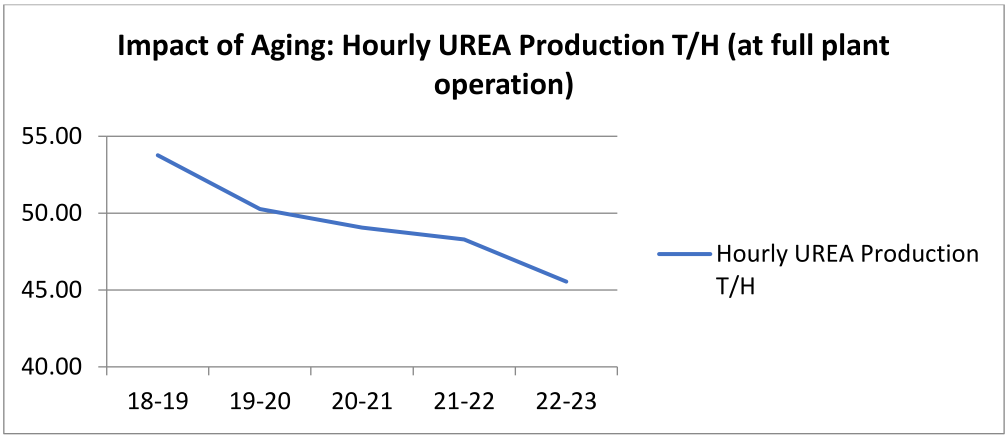
EXECUTIVE SUMMARY

Enhancing energy efficiency is recognized as the swiftest and most economical approach to tackling issues related to energy security, the environment, and the economy. Improvements in energy efficiency involve lowering the energy consumption associated with a specific service or level of activity.

The factory's total energy consumption was assessed, revealing the relation between the annual production and the specific energy consumption. This includes natural gas as feed, natural gas as fuel and other energy sources. The energy-intensive urea production process was scrutinized. Opportunities for optimizing equipment efficiency and streamlining operational procedures were identified, potentially reducing energy consumption by **15.99%**.

This audit is performed in coordination with the Sustainable and Renewable Energy Development Authority (SREDA) and Deutsche Gesellschaft für Internationale Zusammen-arbeit GmbH, GIZ. The purpose of this analysis is to provide the Factory Management insight into the energy savings potential that exists within facilities at Chittagong Urea Fertilizer Company. This audit also gives the picture of this factory’s position against global benchmark of energy use for 1T of Urea production. Energy Efficiency changes and upgrades requires support from the factory administration, operations personnel and the guardian to the factory (BCIC) in order to maximize the savings and overall benefit. The efficiency improvement in such a huge facility, which is a key consumer of energy in Bangladesh, provides a benefit for the environment as well as the economy of this country. Through this report it has been demonstrated that there is a great potential for energy savings and infrastructure improvements at Chittagong Urea Fertilizer Company. The Energy Conservation Measures (ECMs) identified within the report represents the potential savings at the facilities. It is recommended to consider all ECMs as part of the facilities commitment to save energy, reduce emissions, and lower operating costs. The audit team recommends proceeding with the implementation of all ECM’s that provide a calculated simple payback less than three years. All of the ECM’s presented in this report have been categorized into three groups defined as Low Cost (most benefit) investment ranges from BDT 0 to 1,200,000, Medium-cost investment ranging from BDT 1,200,000 to 4,000,000 years, and high investment ranging from BDT 4,000,000 to above.

The factory has been running for last 37 years. The management is doing an excellent job to keep the factory fit for operation but there is an impact of aging. The efficiency of the equip-ment is having downfall due to aging and maintenance practice. The technology is managed by process owner and that is 37 years old as well. Some analysis show the impact of aging on efficiency, fuel consumption and production output.



The team assessed the efficiency of major utility systems. The efficiency scenario is:

System Efficiency	
Power Generation	24.71%
Steam Generation (utility)	77.06%
Pump (WTP)	57.60%

It is evident that aging is a factor. But the other factor is operation and maintenance practice which is mainly assessed by the audit team. There is a lot of scope to improve in operation and maintenance which may lead a saving of significant amount. The overall maintenance practice should be taken under consideration and the housekeeping to be improved. There is a strong saving potential through some small and housekeeping measures.

Power generation efficiency is very low because of low load condition of turbines. For reliability, factory is keeping both turbines in running condition which is not efficient in terms of fuel as well as operation. The steam generation system efficiency is not very good as well considering the modern boilers. Efficiency monitoring and reporting can be included in present operation and maintenance data management. Energy management is to be embedded in present operation and maintenance practice.

Ammonia Production and Specific Energy Consumption:

Table 14: Energy Consumption Benchmark for Ammonia Production

Financial Year	Ammonia Production (T)	Specific Energy Consumption (GJ/T)	Specific Energy Consumption (mcf/T)
2018-2019 to 2022-2023	393,760	68.1	68.59

Urea Production and Specific Energy Consumption:

Table 15: Energy Consumption Benchmark for Urea Production

Financial Year	Urea Production (T)	Specific Energy Consumption (GJ/T)	Specific Energy Consumption (mcf/T)
2018-2019 to 2022-2023	609,750	43.98	44.29

*** Calculation is done on NCV basis (38109 KJ/m^3)

The team identified 15 primary energy efficiency measures. The technical applicability and financial feasibility is analyzed for each measure and a recommendation is made.

Low Cost Energy Efficiency Measures

Table 16: Low-Cost Energy Efficiency Measures

SL No.	Energy Efficiency Measures (EEM)	Investment Cost		Annual Savings						% share of of Identified Savings		IRR (%)
		BDT	Equ. USD	Nm³	Electricity in kWh	GJ	TOE	t-CO2 (MT/yr)	BDT	GJ	BDT	
1	Improvement of Combustion Efficiency of Utility Plant Boiler	1,000,000	8,696	963,308	-	33,817	692	1,965.15	46,238,803	57.29	34.34	4,623
2	Replacement of Faulty Steam Traps.	480,000	4,174	67,612	-	2,373	49	137.93	1,301,184	3.87	14.20	271
3	Providing Insulation on Exposed Utility Boiler Drums.	300,000	2,609	11,118	-	390	8	23	177,892	0.66	10.30	59
4	Providing Insulation on Exposed Steam Valves and Flanges	400,000	3,478	30,640	-	1,076	22	62.51	3,074,373	1.82	13.74	769
5	Providing Insulation on Exposed Steam Distribution & Condensate Return pipelines.	1,200,000	10,435	668,042	-	23,451	480	1,362.81	9,085,372	39.73	41.21	757
6	Reducing the Air Compressor Discharge Pressure.	-	-	35,884	-	239	5	44.40	644,744	0.40	-	-
	Total	3,380,000	29,391	1,776,604	-	61,107	1,250	3,624	59,877,624	100.00	100.00	

Medium Cost Energy Efficiency Measures

Table 6: Medium-Cost Energy Efficiency Measures

SL No.	Energy Efficiency Measures (EEM)	Investment Cost		Annual Savings						% share of of Identified Savings		IRR (%)
		BDT	Equ. USD	Nm³	Electricity in kWh	GJ	TOE	t-CO2 (MT/yr)	BDT	GJ	BDT	
1	Optimize Boiler Blowdown By Installing Automatic Blowdown Control Valves at Utility Boilers.	3,000,000	26,087	9,010,036	-	316,295	6,472	18,380.47	270,301,067	97.74	42.86	172
2	Installation of Automatic Blowdown Control Valve to minimize Blowdown Loss at NH3 plant Aux Boiler.	4,000,000	36,364	207,985	-	7,301	149	424.29	4,781,864	2.26	57.14	122
	Total	7,000,000	62,451	9,218,021	-	323,596	6,622	18,805	275,082,931	100.00	100.0	

High Cost Energy Efficiency Measures

Table 17: High-Cost Energy Efficiency Measures

SL No.	Energy Efficiency Measures (EEM)	Investment Cost		Annual Savings						% share of of Identified Savings		IRR (%)
		BDT	Equ. USD	Nm³	Electricity in kWh	GJ	TOE	t-CO2 (MT/yr)	BDT	GJ	BDT	
1	Refurbishing/ Modification of Feed Water Economizer	60,000,000	521,739	9,010,036	-	316,295	6,472	18,380.47	144,160,569	50.74	22.46	239
2	Use of Boiler blowdown water to preheat polisher water	10,000,000	86,957	356,475	-	12,514	256	727.21	10,694,240	2.01	3.74	56
3	Use of Boiler Blow Down Water As Cooling Tower Make-Up Water	10,000,000	86,957	-	-	-	-	-	24,480,000	-	3.74	245
4	Cleaning Of Condenser (Fouling & De-Scaling) Of NH_3 Plant.	100,000,000	869,565	7,186,457	-	252,279	5,162	14,660.37	114,983,319	40.47	37.43	115
5	Preheating condensate water extracting waste heat from NH_3 Plant Boiler Blowdown.	20,000,000	181,818	277,642	-	9,747	199	566.39	5,747,878	1.56	7.49	26
6	Improve existing lighting systems by more energy efficient LED lamps	11,222,320	102,021	510,915	526,861	6,322	129	1,176.66	15,454,602	1.01	4.20	135.82
7	Replacement of existing Ceiling fans by more energy efficient fans	32,500,000	295,455	261,828	270,000	3,942	81	733.65	7,920,000	0.63	12.16	23.32
	Total	243,722,320	2,144,511	17,603,353	796,861	593,702	12,149	36,445	323,440,607	100.00	100.00	

Financial Assessment of Efficiency Measures

Table 18: Financial Assessment of Energy Efficiency Measures

No.	Energy Efficiency Measures (EEM)	Investment (BDT)	Financial savings per year (BDT)	Payback period (Years)	IRR (%)	NPV (BDT)	Project lifetime (Years)
1	Improvement of Combustion Efficiency of Utility Plant Boilers (3 Nos)	1,000,000	46,238,803.20	0.02	4,623	110,057,803	3.00
2	Refurbishing/ Modification of Feed Water Economizer	60,000,000	144,160,569.22	0.42	239	751,149,234	10.00
3	Use of Boiler blowdown water to preheat polisher water	10,000,000	10,694,239.57	0.94	56	22,110,168	10.00
4	Use of Boiler Blow Down Water As Cooling Tower Make-Up Water	10,000,000	24,480,000.00	0.41	245	128,201,047	10.00
5	Optimize Boiler Blowdown By Installing Automatic Blowdown Control Valves at Utility Boilers (03 Nos).	3,000,000	5,181,883.67	0.01	172	26,162,385	10.00
6	Replacement of Faulty Steam Traps.	480,000	1,301,184.20	0.37	271	4,210,477.83	5.00
7	Providing Insulation on Exposed Utility Boiler Drums.	300,000	177,891.58	1.69	59	705,124	10.00
8	Providing Insulation on Exposed Steam Valves and Flanges	400,000	3,074,373.48	0.13	769	10,682,427	5.00
9	Providing Insulation on Exposed Steam Distribution & Condensate Return Line.	1,200,000	9,085,371.67	0.13	757	31,550,732	5.00
10	Cleaning Of Condenser (Fouling & De-Scaling) Of NH3 Plant.	100,000,000	114,983,318.59	0.87	115	549,217,376	10.00
11	Reducing the Air Compressor Discharge Pressure.	-	644,744.46	-	-	0	10.00
12	Preheating condensate water extracting waste heat from NH_3 Plant Boiler Blowdown.	20,000,000	5,747,877.63	3.48	26	12,476,791	10.00
13	Installation of Automatic Blowdown Control Valve to minimize Blowdown Loss at NH3 plant Aux Boiler.	4,000,000	4,781,863.75	0.84	122	24,956,550	10.00
14	Improve existing lighting systems by more energy efficient LED lamps	11,222,320	15,454,602.24	0.73	135	44,488,062	5.00
15	Replacement of existing Ceiling fans by more energy efficient fans	32,500,000	7,920,000.00	4.10	23.32	21,442,047	10.00
	Total	254,102,320	393,281,978.79			2,484,348,980	

Summary of Energy Saving Potentials

Table 19: Summary of Energy Savings Potentials

Description	Annual Energy Use and Energy Savings Potentials			Annual Cost and Cost Saving Savings Potentials		GHG emission Reduction
	Natural Gas in SCM	Electricity in kWH	GJ	BDT	USD	TCO_{2-e}
Annual Energy Usage	206,332,038	3,550,400	7,256,008	3,301,312,611	28,707,066	423,296
Savings from EEMs	19,803,075	796,861	669,663	393,281,979	3,419,843	54,302
Savings Potential	9.60%	22.44%	9.23%	11.91%		12.83%

1. Electricity importing from BPDB owing to mainly operating the pump house located 20 km away from the CUFL premises. The imported electricity is calculated by averaging the previous five years electrical energy imported from BPDB by this factory.

2. The electricity saving percentage is calculated with respect to the electrical energy imported from BPDB. For saving comparison the energy audit team considers the boundary condition of the factory.

3. The use of electricity in general load like lighting and fan is considered as 70% from STG generation and 30% from Grid power.

4.

Electricity	1 kWh=	0.0036	GJ	0.67	kg CO2/kwh
NG	1 SCM=	0.03510471	GJ	2.04	kg CO2/SCM
Diesel	1 Liter Diesel=	0.038	GJ	2.66	kg CO2/L

Emission Factor Data: DOE & DEFRA-2023

Chapter 1: Factory Description

BACKGROUND

To advance sustainable practices and enhance energy efficiency within electricity and heat-intensive facilities, including power plants and industrial complexes, SREDA and GIZ jointly organized the "Advanced Level Hands-on Energy Audit Training on Fertilizer Industries Benchmark Development." This program took place at Chittagong Urea Fertilizer Limited (CUFL) in Chittagong, Bangladesh, spanning from November 24 to December 1, 2023.

Established in 1987 in Rangadia, Anwara Upazila, Chittagong District, CUFL stands as a vital entity in Bangladesh's fertilizer industry. With an annual installed capacity of 5, 61,000 MT Urea and 3,30,000 MT Ammonia, the facility relies on indigenous natural gas as its primary raw material and fuel. CUFL was instituted by the Government of Bangladesh (GOB) with the overarching objectives of meeting domestic nitrogenous fertilizer demand, bolstering crop production, and reducing reliance on foreign currency.

Having surpassed its prime production period and operated for 36 years, CUFL faced challenges stemming from the scarcity and rising costs of natural gas. The initial design, formulated during the gas surplus of the Eighties, encountered sporadic disruptions, impeding production processes. Acknowledging the need for a transformative approach, SREDA and GIZ took the initiative to showcase the untapped potential for energy savings and establish an energy benchmark in Bangladesh's fertilizer industry. This led to the implementation of an energy audit at CUFL.

A team of certified energy auditors conducted the audit during the specified period, aiming to improve the energy efficiency (EE) of the factory through a combination of technical and organizational measures. The envisioned outcomes include not only lower energy costs but also a significant reduction in CO2 emissions. This initiative underscores the commitment of SREDA, GIZ and CUFL to propel the fertilizer industry towards sustainable and energy-efficient practices, aligning with broader environmental and economic goals.

This background sets the stage for the subsequent audit report, which will delve into the findings, recommendations, and potential avenues for further improvements identified during the energy audit at Chittagong Urea Fertilizer Limited.

Figure 18: Location of Chittagong Urea Factory.

1.2. Objectives of the Energy Audit

The objective of the energy audit at Chittagong Urea Fertilizer Factory is to systematically assess and analyze the energy consumption patterns and efficiency of various processes within the facility. The primary goals of conducting an energy audit in this context include:

i. Identifying Energy Consumption Patterns
ii. Determine the efficiency of energy use in various processes and identify areas where energy is being wasted.
iii. Identify opportunities for reducing energy costs by optimizing energy consumption, improving efficiency, and implementing cost-effective energy-saving measures.
iv. Identify opportunities for reducing carbon emissions.
v. Recommend upgrades to existing technologies or equipment to enhance energy efficiency.
vi. Promote awareness among employees about energy conservation and efficiency.
vii. Identify any potential risks associated with energy consumption, including safety concerns and reliability issues.

By achieving these objectives, the fertilizer factory can enhance its overall energy performance, reduce operational costs, and contribute to sustainability goals.

1.3. Scope of Energy Audit

The scope of an energy audit at Chittagong Urea Fertilizer factory is comprehensive and involves a detailed examination of energy consumption, production processes, and potential areas for improvement. Here are key aspects included in the scope of the energy audit of fertilizer factory:

viii. Overall Energy Consumption Analysis and Benchmarking: Assess the total energy consumption of the facility, including electricity, natural gas, and other energy sources. Break down energy consumption by different processes and operations within the factory.

ix. Process Energy Analysis: Evaluate the energy intensity of key production processes involved in urea manufacturing.

x. Examine the efficiency of equipment such as compressors, pumps, boilers, and steam turbines.

xi. Utility Systems Evaluation: Analyze the efficiency of utility systems, including steam and electricity generation.

xii. Examine the energy efficiency of ammonia synthesis, which is a key precursor in urea production.

xiii. HVAC and lighting systems assessment.

xiv. Explore opportunities for capturing and utilizing waste heat generated during various processes. Recommend strategies for implementing waste heat recovery systems to improve overall energy efficiency.

xv. Evaluate the efficiency of process control systems and instrumentation.

xvi. Identify opportunities for optimizing control strategies to enhance energy performance.

xvii. Assess the effectiveness of existing energy management practices within the facility. Recommend improvements in energy monitoring, reporting, and management systems.

xviii. Conduct a life cycle cost analysis for potential energy-saving measures. Estimate the rough initial investment and assess the financial feasibility with respect to long-term operational and maintenance costs.

xix. Explore opportunities for integrating renewable energy sources, such as solar into the facility's energy mix.

xx. Evaluate the environmental impact of the facility's energy consumption, with a focus on carbon emissions and other pollutants.

1.4. METHODOLOGY

Based on the scope of work, the following steps were followed during the Energy Audit:

- A field survey was conducted towards the collection of existing operational information and data pertaining to the project area.
- Secondary data was collected from factory concerns. Assigned Engineer, supervisor, operators for machines were involved in the process while collecting data.
- The technical aspects of the existing facilities were understood and noted down to be analyzed later. It was necessary to analyze any further possible energy-efficient methods or techniques to follow.
- Potential power-consuming sources were identified.
- Catalogs of different machines were collected.
- To collect periodic consumption data, bills, monthly and yearly reports were accumulated.
- On the basis of collecting relevant data, identification of potential impacts has been done using the checklists method.
- Measuring power through different sensor-based devices.

1.5. FACTORY DESCRIPTION

Chittagong Urea Fertilizer Limited was built in 1987 in Rangadia, Anwara Upazila, Chittagong District, Bangladesh. It was built by the Japanese Toyo Engineering Corporation. The factory has a rated capacity to produce 1,700 tonnes of urea and 1000 tonnes of ammonia per day. The general information of the factory is as follows:

Table 20: Factory Construction Overview

General Contractor	M/S. Toyo Engineering Corporation (Japan)
Type of contract	Cost plus fees.
Financial sources	ADB, ADFAED, CIDA, IDA, IDB, OECF, SFD, Bangladesh Bank.
Capital Invest/Project cost	TK.153119.31Lac
Year of establishment	1987
Construction period	December 1984 to October 1987 (35 months)
Commercial production Date	01-July,1988
Total Area	532.33 Acres
Daily requirement of Raw Material& Utility	
a) NG Total	47.61MMCF
b) Electricity	264 MWH
c) Water (make-up)	23,000 MT

CAPACITY OF THE KEY AUXILIARY FACILITY ARE AS FOLLOWS:

Table 21: Capacity of the key auxiliary facility

Auxiliary/Ancillary/special facilities:	
Power Generation (STG)	2 X 12 MW
Emergency power Generation	2 X 2 MW
c) Ammonia storage	5000MT
d) Bulk urea storage	85,000MT
e) Bagged urea storage	10,000MT
f) Nitrogen unit	550 Nm3/h
g) Package Boiler	85x3 MT/h
h) Demi water unit	140x2 MT/h
i) Water storage	25,900 MT
j) Bagging plant	220 MT/h
k) Polythene Bag Plant	12X106/ h
l) Instrument Air Compressor	1800 X 2 Nm3
m) Ship loader	220 MT/h
n) Export jetty	16,000 MT/D
o) Workshop	Machining/Fabrication

1.6. PRODUCTION PROCESS

The major processes of the Chittagong urea fertilizer factory can be classified into three major sections like production of ammonia, production of urea and the utility. The design/process licensor of ammonia and urea production process is MW Kellog (U.S.A.) and the TEC-MIC (Total recycle C-process) respectively.

1.6.1 Ammonia Production Process

The primary raw material for urea production is ammonia. Ammonia is synthesized through the Haber-Bosch process, which involves the reaction of nitrogen and hydrogen under high pressure and temperature in the presence of a catalyst. The production process of ammonia is as follows:

I. NG is preheated with LP steam and then spitted into two streams i.e., fuel gas and process gas.

II. The pre-heated process NG is mixed with hydrogenation gas from synthesis Gas Compressor and then further heated in the flue gas duct of primary reformer.

III. The mixed gas passes through desulfurization reactor consisting of Cobalt Molibodate catalyst bed and Zinc oxide catalyst beds where sulfur compounds are removed.

IV. The desulfurized NG is mixed with process steam and fed to the primary reformer in presence of Ni-catalyst at a pressure of 28.5 Kg / cm2 & a temperature of 400° C. The reactions are endothermic. The required thermal energy is supplied by a mixture of fuel gas, purified gas from co2 absorber and purge/ flash gases. The primary reformer is box type and top firing with preheated forced draft air. The hot flue gases leaving the primary reformer is led to the flue gas duct where the heat is recovered by heat exchanger. The cooled flue gases are rated to the stack via I.D. fan.

V. The hot process gas from the primary reformer is sent to Secondary Reformer where the preheated process air compressed by process air compressor is admitted.

VI. Equilibrium conditions between the reaction products are established in presence of Ni-catalyst. As a result, CH_4 content is reduced.

VII. The hot reformed gas from the Secondary Reformer passes through process gas cooler & boiler feed water pre-heater and then fed to high temperature shift converter.

VIII. The reformed gas is subjected to CO shift reactor in two adiabatic stages i.e. high temperature Shift converter & low temperature Shift converter. The reaction is exothermic. The hot process gas leaving HTSC which contains the catalyst of ferrous oxide and Chromium oxide is cooled in Methanator Trim Heater and Boiler feed water pre-heater. The cooled process gas passes through LTSC where the remaining CO and water is further converted to CO_2 & H_2 by the catalyst based on Cu, Zn & Al at low temperature.

IX. The process gas flows through two stage CO_2 absorber bottom to top and is scrubbed by hot potassium carbonate solution.

X. The purified gas leaving the top of the absorber is spitted into two streams after knocking out drum. Most of the purified gas is further processed in Methanation section and a part of purified gas is routed to the fuel gas heater.

XI. The rich hot potassium carbonate solution leaving the bottom of the absorber is fed to the regenerator via expansion turbine.

XII. The removed CO_2 & water vapor leaving the top of the regenerator is cooled. The cooled CO_2 after the condensate is separated, is fed to urea plant.

XIII. The purified gas from CO_2 absorber is preheated by feed/ effluent heat exchanger and its temp. is adjusted by Methanator Trim Heater before it enters Methanator. In the methanator, the residual CO &CO_2 are hydrogenated in presence of Ni-catalyst. The reaction is exothermic. The hot methanated gas is cooled.

XIV. The cooled process gas mixture contains H_2&N_2 at a ratio of 3:1 and with traces of CO_2 &CO is sent to the synthesis gas compressor after the condensate is separated. Formation of NH_3 in the reaction system takes place at a pressure of 308 Kg/cm2G and a temp. of 500°C. The reaction is exothermic.

XV. The converted gas leaving the bottom of the converter at steam. of 370°C is fed into waste heat boiler generating medium pressure steam (42 kg/cm2G) and gas is cooled.

XVI. In ammonia chiller, the final cooling of product gases is done by evaporating liquid ammonia.

XVII. Before entering separator, the gas/ammonia mixture from the chiller is mixed with compressed make up synthesis gas. The condensed ammonia is collected in the separator and flashed into flash drum which is operated at low pressure.

XVIII. The liquid ammonia from separator is preheated by heat exchanger and sent to Urea Plant.

1.6.2 UREA PRODUCTION PROCESS

Ammonia is combined with carbon dioxide in a stripper tower to form ammonium carbamate. This reaction is reversible, and the equilibrium is shifted towards urea formation by continuously removing carbon dioxide.

I) Compressed CO_2 & NH_3 are fed into synthesis section at a pressure of 140 kg/cm2 & at a molar ratio NH_3: CO_2 = 2 :8 where due to exothermic reaction Ammonium Carbamate will be formed at a temp. of 170-180°C.

II) The reaction mixture, leaving the reactor is distributed over the tubes of the stripper. The gases leaving at the top of the stripper are led to the HP condenser. A major part of the stripper off-gases, together with the fresh ammonia feed is condensed here in to carbamate at a temp, of approx. 170°C. The condensate and remaining non-condensed ammonia & CO_2 are subsequently introduced into the bottom of the reactor. In the reactor conversion of carbamate takes place & 60% urea solution is obtained.

III) The reactor mixture descends through the down comer line to stripper. Essentially all the non-converted ammonia and carbon di- oxide are recovered from the urea-carbamate solution raised to 135°C as a result of which is caused to decompose leaving the bottom part of the stripper.

IV) The gas-liquid mixture is introduced in a rectifying column. The solution is sent from bottom part of the rectifying column to a heater where its temperature regains.

V) In the separator, the gas phase is separated from liquid phase. The solution from the rectifying column is passed through a level control valve to the flash tank. In this tank, a slight vacuum is maintained. Due to this pressure drop a considerable amount of water vapor as well as some ammonia will escape from the solution. The solution is fed into a urea storage tank.

VI) The urea solution pump transports the urea solution to the 1st stage evaporator, in which it is exposed to a vacuum and simultaneously heated up to 125°C to 130°C. here the concentration of the urea solution is increase to about 96%. The liquid-vapor or mixture is separated with separator of the 1st stage evaporator section. The vapor from this separator is condensed in the 1st stage evaporation condenser. The normal operating pressure in the 1st stage evaporation section is about 0.3kg/cm2 (abs.)

VII) The urea solution then flows into the 2nd stage heater where the normal operating pressure will be about 0.03kg/cm2 (abs).

Here the concentration of urea is increased to 99.78 %. The urea melt from the 2nd stage evaporation is discharged to the suction side of the urea melt pump and is transported to top of the prilling tower.

VIII) The urea melt is fed to the spinning prill bucket. The bucket distributes the urea melt in fine droplets over the cross section of the tower. During their fall in the tower the droplets solidify in to prills. The heat is carried off by the air aspirated through holes at the bottom of the tower.

IX) The urea prills are collected on the bottom of the tower and scraped into a slot. Where upon a belt conveyor transport then to the storage section.

X) The final urea product is then bagged for distribution and storage. Quality control measures are implemented to ensure that the product meets specified standards.

Energy Use Scenario

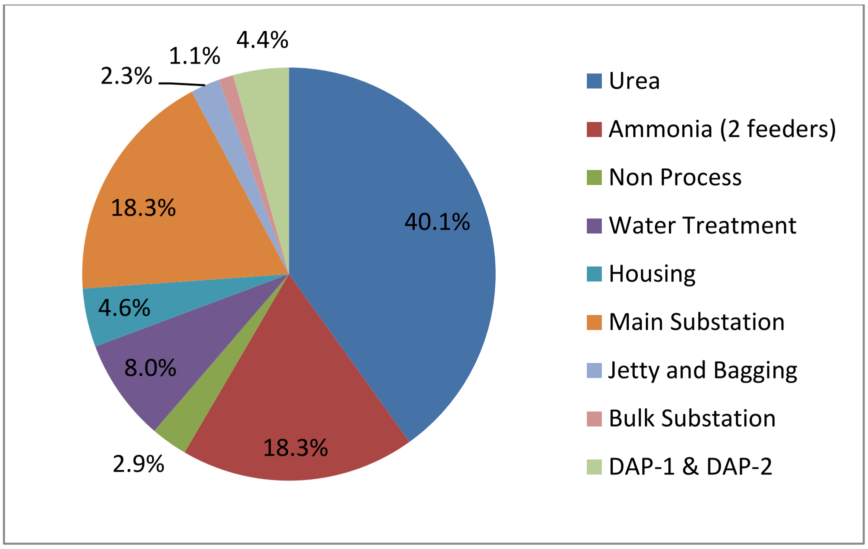
For the years 2017-18 to 2022-23

		Energy Consumption				Energy Cost		Emission
SL	Energy Type and use	Natural Gas (m^3)	Electricity kWh	GJ	%	BDT	%	t-CO_2 eq
1	Natural Gas for Ammonia Plant	623,712,193	-	22,001,381	60.35	9,979,395,088	59.77	1,272,373
2	Natural Gas for Utility Plant	407,947,998	-	14,390,322	39.47	6,527,167,968	39.09	832,214
3	Electricity from BPDB	-	17,752,000	63,907	0.18	189,946,400	1.14	11,894
	Total	1,031,660,191	17,752,000	36,455,610	100.00	16,696,509,456	100.00	2,116,481

Electrical Power Use Scenario At Full Load Condition

Electricity is mainly generated from STG plant. The plant imports some electricity as well from grid. Below is the picture of electricity usage pattern by areas:

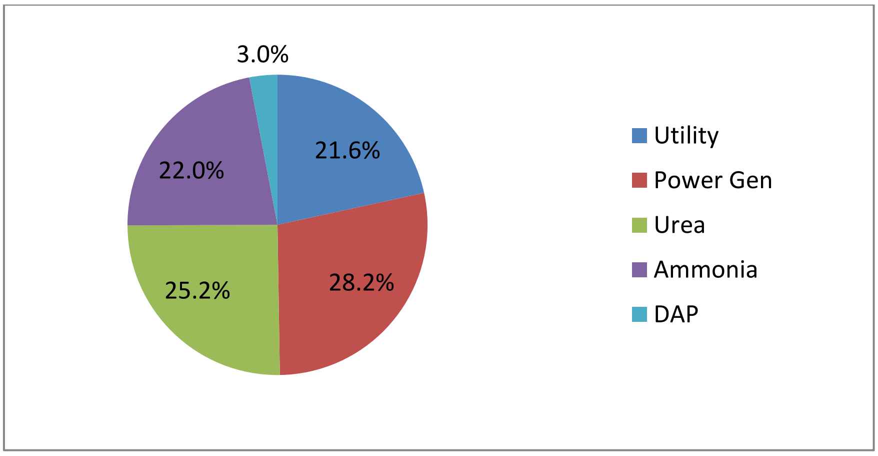
Section	Load (MW)
Urea	3.5
Ammonia (2 feeders)	1.6
Non Process	0.25
Water Treatment	0.7
Housing	0.4
Main Substation	1.6
Jetty and Bagging	0.2
Bulk Substation	0.1
DAP-1 & DAP-2	0.38
Total Load	8.73



Steam use by Operation

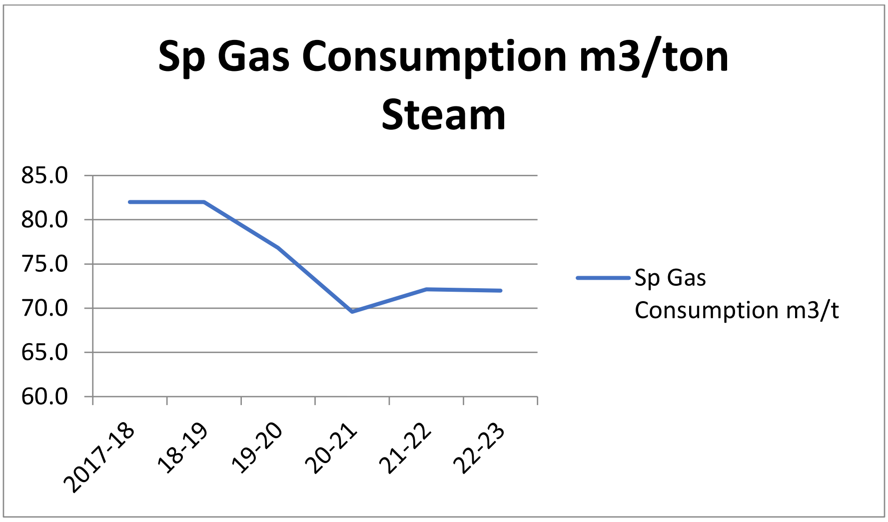
Steam is used at different function of the plant. The utility export some steam to DAP as well.

Steam Use (T)					
Year	Utility	Power Gen	Urea	Ammonia	DAP
2017-18	2,58,613	2,70,514	2,24,507	2,44,790	20,886
18-19	2,39,583	2,73,727	2,69,282	2,33,410	11,620
19-20	2,06,365	2,40,726	55,157	1,38,577	32,132
20-21	2,66,432	3,41,010	3,39,582	3,21,377	43,745
21-22	2,36,652	3,66,353	5,08,908	2,99,526	39,959
22-23	2,03,728	3,49,410	2,50,243	2,02,941	49,400



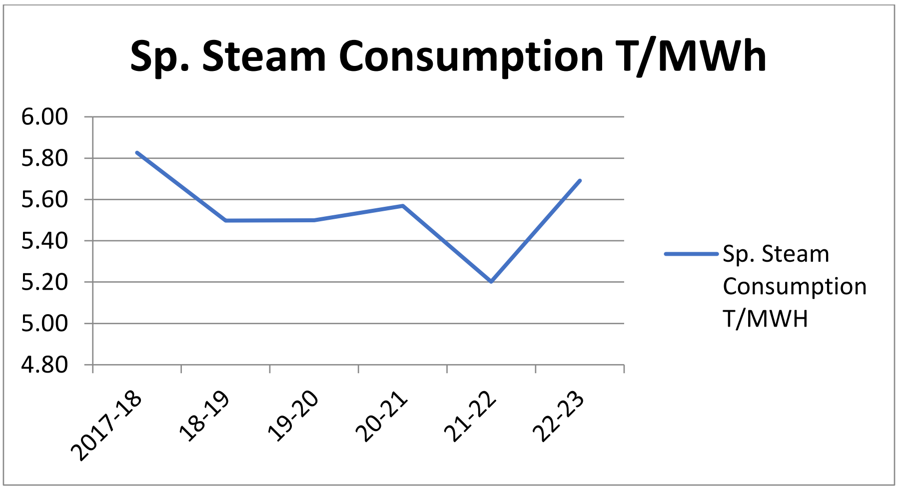
Specific Gas Consumption for Steam Generation

Natural gas is used both as feed gas at ammonia plant and fuel at utility plant. At utility plant gas is used for steam generation.



Specific Steam Consumption for Power Generation

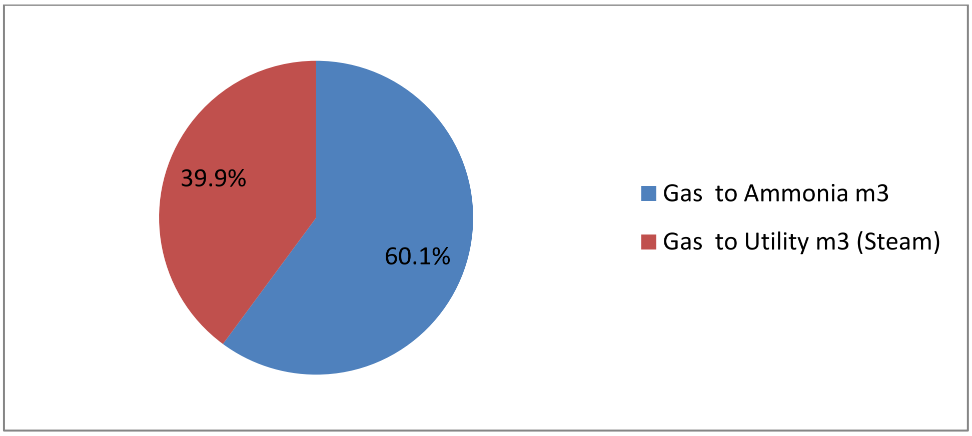
Major part of steam from utility is used for power generation through STG. The steam consumption varies from 5.2 ~5.8 Ton/MWh.



Natural Gas Consumption

Almost 40% gas is used in Ammonia plant and rest is used at utility plant.

Year	Gas to Ammonia m3	Gas to Utility m3 (Steam)
2017-18	117,163,466	83,583,420
18-19	138,999,423	84,265,004
19-20	34,704,309	51,702,943
20-21	143,490,392	91,309,715
21-22	216,970,880	104,692,702
22-23	89,547,189	75,977,634



Chapter 2: Performance Assessment

The Chittagong Urea Fertilizer Factory is a very energy intensive factory. The performance assessment of equipment of the fertilizer factory is crucial for ensuring the efficiency, reliability, and overall effectiveness of the production processes. The efficiency of the ammonia synthesis process and subsequent urea synthesis steps plays a significant role in energy intensity. Improvements in reaction kinetics and heat recovery systems can contribute to reduced energy consumption. The cooling and condensation steps are critical in the urea production process. Effective heat exchange systems can contribute to energy efficiency by recovering and reusing heat, thereby reducing the overall energy input required. The efficiency of utility systems, such as boilers and compressors, contributes to the energy intensity of the entire facility.

2.1 PERFORMANCE OF AMMONIA PLANT

Table 22: Performance of the ammonia plant

Financial Year	Ammonia Production	Specific Energy Consumption	Specific Energy Consumption (mcf/Ton)
	1000xT	*GJ/T*	*mcf/T*
2018-19	71.02	84.99	85.59
2019-20	12.05	147.87	148.93
2020-21	90.66	71.83	72.34
2021-22	159.82	52.68	53.06
2022-23	60.2	68.1	68.59

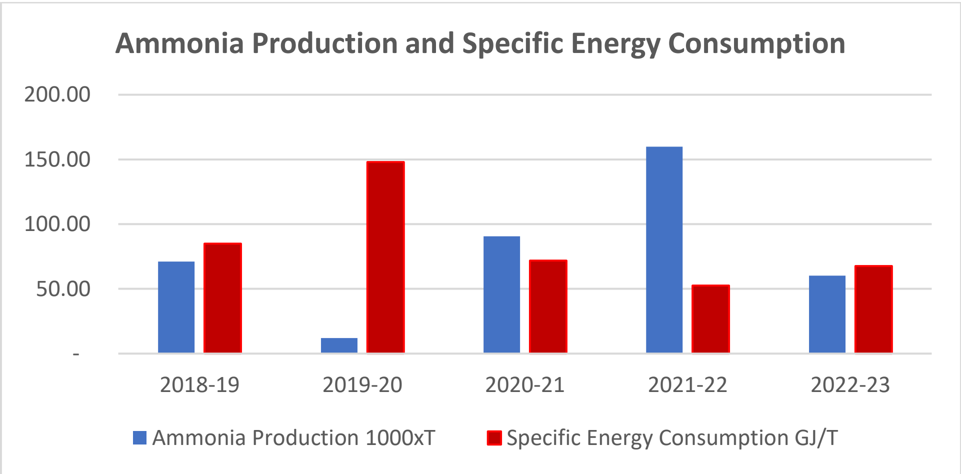


Figure 19: Ammonia production and specific energy consumption

2.2 Performance of Urea Plant

Table 23: Performance of the urea plant

Financial Year	Urea Production (1000xT)	Specific Energy Consumption (GJ/T)	Specific Energy Consumption (mcf/Ton)
2018-19	120.28	36.44	36.7
2019-20	7.19	89.53	90.17
2020-21	141.72	42.05	42.35
2021-22	247.1	37.2	37.47
2022-23	93.46	42.45	42.75
Cumulative	609.75	43.98	44.29

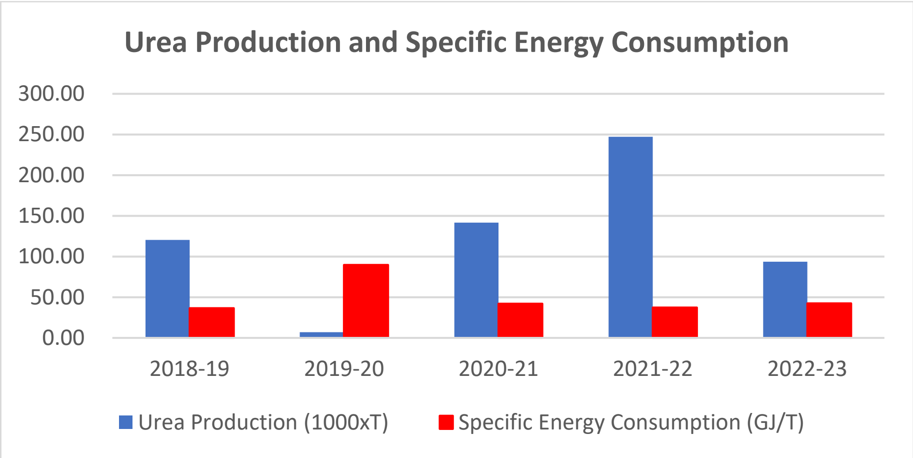


Figure 20: Urea production and specific energy consumption

2.3 PERFORMANCE of Utility Section

2.3.1 Utility Boiler:

Actual Measured Flue Gas Analysis Data

Table 24: Measured flue gas analysis data

Parameter	Unit	Value
O_2	%	7.2
CO	ppm	172
CO_2	%	7.83
Flue Gas Exit Temperature	°C	201

Boiler Efficiency (Indirect Method):

Table 25: Boiler Efficiency (Indirect Method)

Description	Boiler Losses (%)
L1. Loss Due to Dry Flue Gas (Sensible Heat)	8.89
L2. Loss Due to Hydrogen in Fuel (H_2)	12.03
L3. Loss Due to Moisture in Air (H_2O)	0.28
L4. Loss Due to Carbon Monoxide (CO)	0.73
L5. Loss Due to Radiation and other unaccounted	1
Indirect Efficiency (100-L1-L2-L3-L4-L5)	**77.06**

2.3.2 STEAM TURBINE:

Table 26: Efficiency of Steam Turbines

Particulars	Measured Value		Unit
	ST-1	ST-2	
Steam Turbine Rated Capacity	12	12	MW
Measured Generator Output	4.2	5.2	MW
Specific Steam Consumption	5.95	5.19	kg/kWh
Steam Turbine Cycle Efficiency	**23.02**	**26.39**	**%**
Avg. Specific Steam Consumption	5.57		kg/kWh
Avg. Steam Turbine Cycle Efficiency	**24.71**		**%**
Avg. Turbine Heat Rate	14,637.85		kJ/kWh
Avg. Unit Heat Rate @ boiler eff. 77%	19,010.20		kJ/kWh

2.3.3 WTP PUMPS:

Pump	Running Condition							
	Flow (M3/H)	Head (M)	Current (A)	Voltage (V)	PF	Pump Input (Kw)	Hyd Power	Efficiency %
Clarifier Pump	724	17.5	84	440	0.81	51.85	34.53	66.60%
Sand Filter Pump	700	32.5	153	440	0.81	94.44	61.99	65.60%
Filter Water Pump	526	26.5	126	440	0.81	77.78	37.98	48.80%
Potable Water Pump	129	51	46	440	0.81	28.4	17.93	63.10%
Demi Water Pump	85	34	29	440	0.81	17.9	7.88	44.00%

AVG. WTP PUMP EFFICIENCY **57.6%**

Chapter 3: Energy Conservation Measures

Reducing energy intensity in Chittagong Urea Fertilizer Company (CUFL) will not only contribute to cost savings but also align with sustainability goals by minimizing environmental impact as well as stepping a foot towards achieving SDG. Continuous improvement strategies, technological advancements, and best practices in energy management are essential for optimizing energy intensity in fertilizer manufacturing processes. Regular energy audits and monitoring can help identify opportunities for improvement and guide efforts to enhance energy efficiency. This process helps identify areas for improvement and implement best practices to enhance energy efficiency. The measures suggested will impact on 5 SDGs (SDG-7, 8, 9, 12, 13).

Figure 21: Save energy.

EEM-1: Improvement of Combustion Efficiency of Utility Plant boiler.

CURRENT CONDITION

All the 3 Utility Boilers use Natural Gas as fuel. The air ratio found high (high O_2 concentration observed in exhaust flue gas), resulting in enormous amount of heat energy losses continuously.

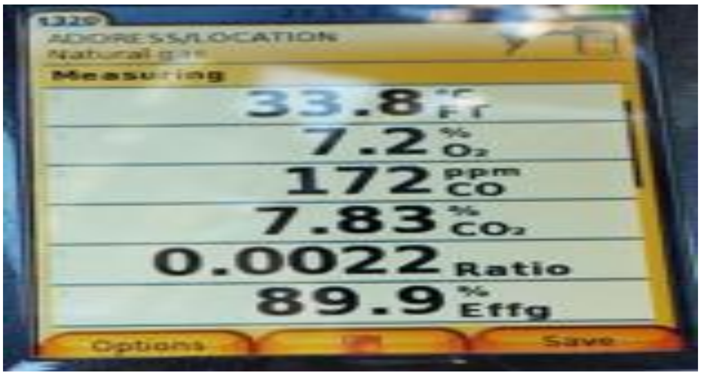


Figure 22: Boiler flue gas analysis

IMPROVEMENT MEASURE

Strengthen combustion control by adjusting air ratio to an appropriate value and reduce heat loss. The adjustment of air and blower controller as well as servicing of blower is assumed as requirement and estimated cost is BDT 1,000,000.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual fuel Savings	28,89,925	Nm^3/yr
Annual savings for three boilers	46,238,803.00	BDT/yr
Investment	1,000,000.00	BDT
Project lifetime	3	Years
Payback period	0.02	Year
IRR	4624	%
NPV	110,057,803	BDT

*** Natural Gas Price is considered @BDT 16 per m^3

EEM-2: Refurbishing/ Modifying Feed Water Economizer

CURRENT PRACTICE

Exhaust temperature of all the Boilers found higher than 200°C. It results heat loss through flue gas which is happening continuously.

IMPROVEMENT MEASURE

Conducting maintenance and tube cleaning (Refurbishing or modifying if necessary) of existing economizer will increase the efficiency of heat transfer. The job will initiate with deep cleaning of economizer, repair/replace tube and servicing of other parts. If the economizers found beyond repair, these are recommended to be replaced. The cost for 3 economizers are estimated as BDT 60,000,000/.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to <u>Annexure-1.</u>

Annual fuel savings	90,10,035.57	m^3/yr
Annual savings for three boilers	144,160,569.22	BDT/yr
Investment	60,000,000.00	BDT
Project lifetime	10	Years
Payback period	0.42	Year
IRR	239.56	%
NPV	751,149,234.20	BDT

*** Natural Gas Price is considered @BDT 16 per m^3

EeM-3: Polisher Water Preheating by Recovery Heat from Boiler Blowdown Water

CURRENT PRACTICE

Hot blowdown water from utility boilers is being discharged presently after quenching by cooling water into effluent treatment plant (ETP) followed by River.

IMPROVEMENT MEASURE

A new heat exchanger to be installed which will collect the heat from boiler blowdown water and supply the heat to Polisher water. That will save the cooling water being used now. The cost of heat exchanger, pumping and piping is estimated as BDT 10,000,000.

Option to heating-up polish water.

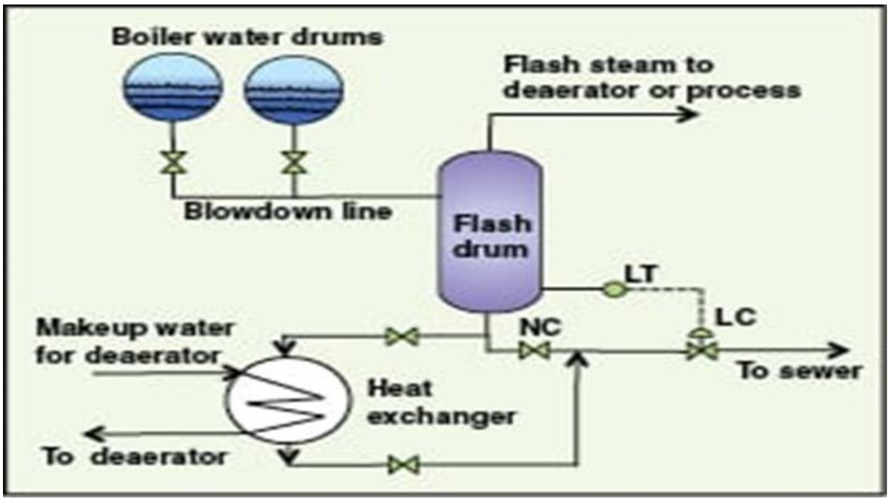


Figure 23: Option to heat-up polish water

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual fuel savings	3,56,474.65	m^3/yr
Annual savings for three boilers	5,703,594.44	BDT/yr
Investment	10,000,000.00	BDT
Project lifetime	10	Years
Payback period	1.75	Year
IRR	56.2	%
NPV	22,110,167.98	BDT

*** Natural Gas Price is considered @BDT 16 per m^3

EEM-4: Use of Boiler Blowdown water as Cooling Tower Make-Up Water

CURRENT PRACTICE

High quality blowdown water currently is being drained; lowering temperature passing through water cooled heat exchanger, into ETP followed by River.

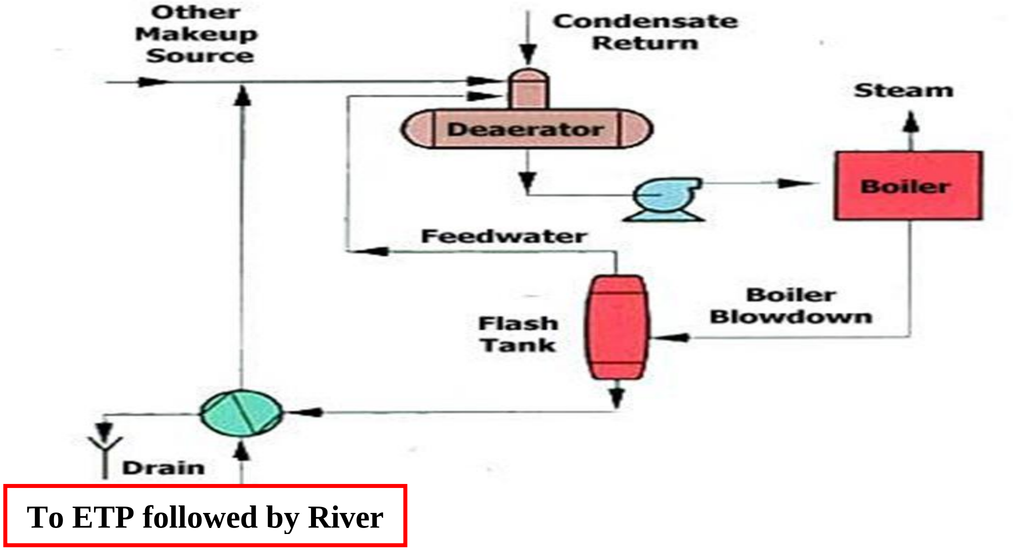


Figure 24: Proposal to use blow down water as cooling water make-up

IMPROVEMENT MEASURE

High quality boiler blowdown water can be used as cooling tower make-up water. It is found that blowdown water quality comply the requirement of cooling tower water quality. This will save cooling tower make-up water, chemical and energy simultaneously.

The arrangement for redirecting water like pumping, piping and other structure will be required. The team estimated a cost of BDT 10,000,000 for the project.

Figure 25: Usage of blow down water as cooling tower makeup water.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual Cooling Tower Make-up Saving	244,800,000.00	kg/yr
Annual monetary savings	24,480,000.00	BDT
Investment	10,000,000.00	BDT
Project lifetime	10	Years
Payback period	0.41	Year
IRR	244.74	%

EEM-5: Minimize Boiler Blowdown by Installing Automatic Blowdown Control Valve.

CURRENT PRACTICE

Currently Boiler Blowdown is done manually. The operators keep the valve in same position despite being variable load operation and water parameters maintaining within the operation limit as no monitoring mechanism is there. This is resulting heavy water loss and heat loss through blowdown.

IMPROVEMENT MEASURE

By installing automatic blowdown control valve regulating based on water parameters like TDS, the said loss can be brought down substantial amount along with extra human effort. The cost of automatic blowdown valve and pipeline for 3 boilers is estimated as BDT 3,000,000.

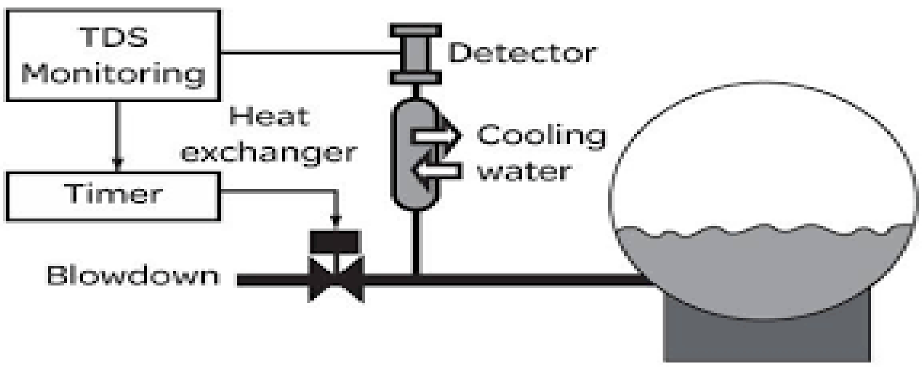


Figure 26: Automatic blowdown control valve

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual fuel saving	2,15,133	m^3/yr
Total Annual Monetary Savings	5,181,883.67	BDT
Investment	3,000,000.00	BDT
Project lifetime	10	Years
Payback period	0.58	Year
IRR	172.43	%
NPV	26,162,385.51	BDT

EEM-6: Heat Recovery by Replacing Faulty Steam Traps.

CURRENT PRACTICE

Most of the Steam Traps of entire (CUFL) plant were not functioning properly. The team observed this during plant visit and it results substantial amount of thermal energy losing continuously.

Figure 27: Defected steam trap

IMPROVEMENT MEASURE

To replace the faulty steam traps by new one. The team estimated a cost of BDT 480,000 from local market for the replacement of 40 steam traps (20mm). This will start giving benefit immediately in terms of fuel and improve overall housekeeping scenario.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual savings from 40 20mm faulty steam trap	1,301,184.40	BDT/yr
Investment	480,000	BDT
Project lifetime	5	Years
Payback period	0.37	Year
IRR	271	%
NPV	4,210,477.00	BDT

EEM-7: Covering Exposed Boiler Drum by appropriate Insulation.

CURRENT PROBLEM

The front sides of boiler drums were found exposed without insulation. High heat loss was occurring though radiation from that surface and it is a safety hazard.

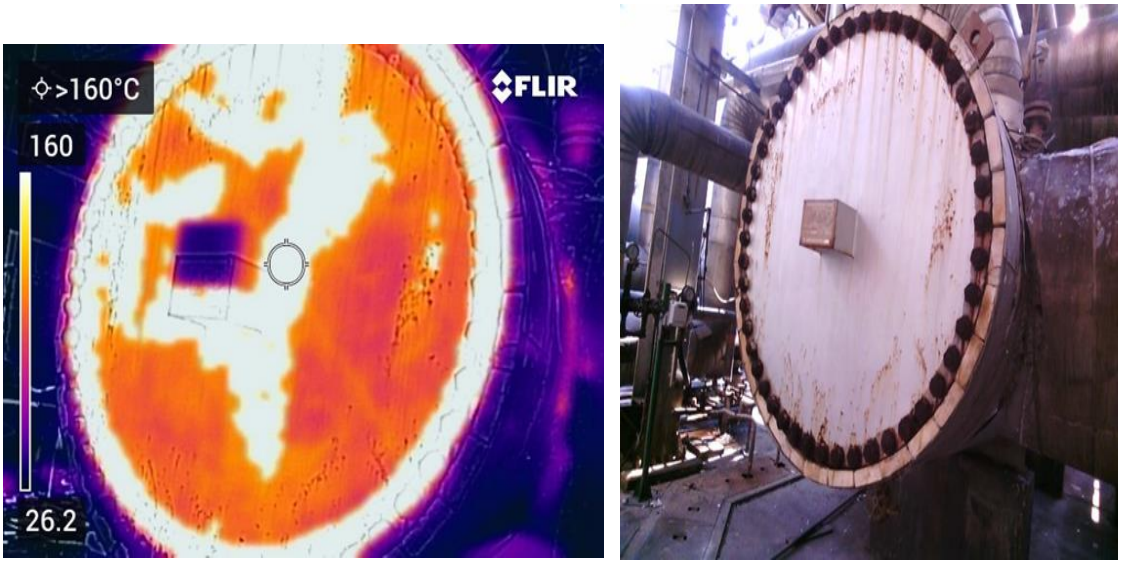


Figure 28: Thermal image of boiler

IMPROVEMENT MEASURE

The 4.5m^2 area of each boiler drum to be insulated properly to prevent heat loss. The insulation cost is estimated as BDT 100,000 for each boiler.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual fuel saving per boiler drum	11,118.22	m^3/yr
Total Annual Monetary savings	177,891.00	BDT/yr
Investment	300,000.00	BDT
Project lifetime	10	Years
Payback period	1.69	Year
IRR	58.71	%
NPV	705,123	BDT

EEM-8: Covering the exposed steam valves with proper insulation

CURRENT PROBLEM

During field visit many steam valves and flanges of different sizes were found exposed without insulation which were resulting a large amount of heat energy continuously dissipating to surrounding. It is a loss of energy and a hazard to health & safety.

Figure 29: Uninsulated portions of Turbine Pump

IMPROVEMENT MEASURE

Properly covering the bare steam valves flanges with thermal insulating materials to Prevent Heat Dissipation and Save Energy. Note that for the sake of soothing labor, only 3”,4”,6” size valves considered during calculation. The team identified 16 nos of valves and the estimated costing is BDT 400,000.

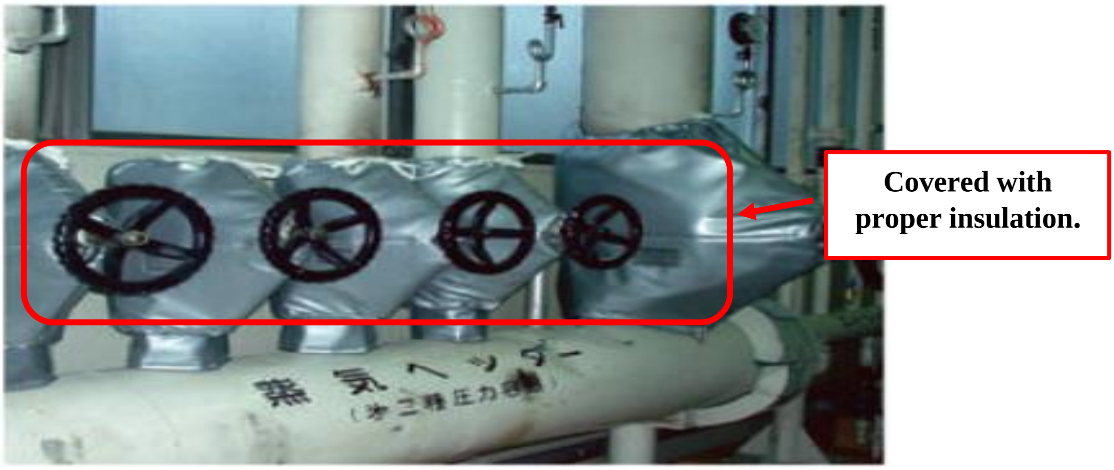


Figure 30: Sample of insulated valves

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual fuel savings	30,639.95	m^3/yr
Monetary saving of 16 nos. different (each 3",4",6" size) of exposed valves	3074373.10	BDT/yr
Investment	400,000.00	BDT
Project Period	5	Yrs
Payback Period (Simple)	0.13	Yrs
NPV	10,682,426.00	BDT
IRR	769	%

EEM-9: Insulating the Exposed Steam Distribution & Condensate Return Line.

CURRENT SCENARIO

During visit some steam distribution pipes and some condensate return pipe found bare without insulation. The pipe surface temperature was found 160° and it was a heat loss.


IMPROVEMENT MEASURE

Properly covering the bare steam pipes and condensate return pipes with thermal insulating materials to prevent heat dissipation and save Energy. The team estimated about 60 m^2 exposed pipe and the costing is identified as BDT 1,200,000.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual fuel savings	567,835.73	$m^3/yr/m^2$
Monetary saving per Year	9,085,371.67	BDT/yr
Investment	1,200,000.00	BDT
Simple Payback Period	0.13	Years
NPV	31,550,721.00	BDT
IRR	757	%

EEM-10: Cleaning of Condenser (Removal of Fouling & Scaling) at NH3 Plant.

CURRENT PROBLEM

The performance of NH_3 plant condenser is suffering by fouling & scaling and as a result plant can't produce rated amount of work. On the other hand, because of augmenting condenser back pressure, steam consumption increased for doing same work done of several turbine driven compressors & pumps. At present, the operation team use to spray fire-fighting water on condenser body to bring down condenser temperature. This is resulting huge amount of treated water loss continuously as well. The heat load on cooling tower increases for this as well.

Figure 31: Defective Condenser

IMPROVEMENT MEASURE

Condenser tubes to be cleaned properly with chemicals/de-scalar to reduce back pressure as well as restoration of efficiency in condenser. This will help to bring down steam consumption to produce finished goods as well as work done on turbine driven equipment (compressors & pumps). The cost of cleaning is estimated as BDT 100,000,000.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual fuel saving	7,86,457.41	m^3/yr
Monetary saving per Year	114,983,318.59	BDT/yr
Investment	100,000,000.00	BDT
Simple Payback Period	0.87	Years
NPV	549,217,376.14	BDT
IRR	115	%

EEM-11: Reducing the Discharge Pressure of Control Air Compressor.

CURRENT PROBLEM

Currently Utility Plant Instrument Air Compressor is running with high discharge pressure which is wasting a significant amount of energy. A large amount of electrical energy can be saved annually by optimizing compressor discharge pressure without hampering system operation. This type of energy saving measure needs no extra capital investment.

Figure 32: Air compressor operating hours

IMPROVEMENT MEASURE

Reduction of compressor discharge pressure from 9.41 to 8.01 Bar.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual electricity saving	66,263.56	kWh/yr
Annual Monetary Saving	574,137.53	BDT/yr
Investment	0	BDT
Simple Payback Period	-	Years
NPV		BDT
IRR	-	%

EEM-12: Preheating condensate water by waste heat from NH_3 Plant Boiler Drum Blowdown water.

CURRENT PRACTICE

A large quantity of hot boiler blowdown water is being drained out continuously with high temperature at NH_3 plant. A huge amount of heat energy is being lost.

Figure 33: Heat Loss with blowdown water

IMPROVEMENT MEASURE

A substantial amount of heat energy can be captured from hot blowdown water by heating condensate water passing through a newly installed heat exchanger which will reduce to fuel use. The heat exchanger, pipeline and other cost is estimated as BDT 20,000,000.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual fuel saving	277,642.35	m^3/yr
Annual cooling tower make-up saving	13,056,000	Kg/yr
Total Annual Monetary Saving	5,747,877.63	BDT/yr
Investment	20,000,000.00	BDT
Simple Payback Period	3.48	Years
NPV	12,476,790.55	BDT
IRR	26%	%

EEM-13: Installation of Automatic blowdown Control Valve to minimize excessive blowdown Loss at NH_3 plant Boiler.

CURRENT PRACTICE

A significant amount of hot blow down water is continuously draining out due to manual operation. As a result the plant is losing significant amount of heat energy as well as treated expensive demineralizer water.

IMPROVEMENT MEASURE

A substantial portion of heat as well as feed water make-up can be saved by installing an automatic blowdown control valve which will assist to elevate operational reliability and reduce human labor & error as well. The cost of blowdown control valve with remote monitoring of parameters is considered as BDT 4,000,000.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual fuel saving	207,985.05	m^3/yr
Feed water flow saving	648	Kg/hr
Total Annual Monetary Saving	4,781,863.75	BDT/yr
Investment	4,000,000.00	BDT
Simple Payback Period	0.84	Years
NPV	24,956,549.80	BDT
IRR	122	%

EEM-14: Improve existing lighting systems by more energy efficient LED lamps.

CURRENT PRACTICE

The plant and all the facilities have around 9000 numbers of 23W fluorescent bulb and 9500 numbers of conventional 34W T8 tube lights.

IMPROVEMENT MEASURE

Replace fluorescent bulbs by 12W LED bulbs; Replace T-8 tubes by 20 Watt LED tube lights.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual energy saving	1,756,205	kWh/yr
Total Annual Monetary Saving	15,454,602	BDT/yr
Investment	11,222,320	BDT
Simple Payback Period	0.73	Years
NPV	44,488,062.37	BDT
IRR	135.82	%

*** Power price is considered at BDT 8.8/kWh

EEM-15: Replacement of existing Ceiling fans by more energy efficient fans

CURRENT PRACTICE

The plant and the facilities have around 5000 numbers of 80-100W traditional ceiling fans.

IMPROVEMENT MEASURE

Replace existing ceiling fans by energy efficient Brush-less Direct Current (BLDC) ceiling fans (35W). The actual cost of BLDC fan is BDT 32,500,000 and the salvage value of existing fans is considered BDT 1,000,000.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Total Annual Monetary Saving	7,900,000	BDT/yr
Annual energy saving	900,000	kWh/yr
Investment	32,500,000.00	BDT
Simple Payback Period	4.1	Years
NPV	22,441,046.76	BDT
IRR	23.3	%

*** Power price is considered at BDT 8.8/kWh

CHAPTER 4: ADDITIONAL RECOMMENDATIONS

RECOMMENDED ACTION: CHECKING THE CATALYSTS AND AGED TUBES OF PRIMARY REFORMER.

It has been observing that the primary reformer uses to running approximately 80% load most of the time since last couples of years because of saving reformer tubes from overheating. Note that a large number of tubes of the same have been suffering by localized heat (hot spot) while operating above 80% load which led to bring down plant factor resulted in lower the efficiency augmenting energy consumption for generating per unit finished product consequently uplifting production cost. After deep dive analysis the energy audit team recommended to the followings.

Action 1: To check catalyst located inside reformer tubes which might be deactivated/saturated/powdered owing to prolong operation (factors like carbon deposition, sintering or impurities in the feedstock) resulted in creating flow resistance during higher load operation, lowering H_2 production consequently generated huge-localized heat followed by overheated tubes material.

Figure 34: Deactivated and broken catalyst.

Action 2: To check the aged reformer tubes and replace if found leakage or crack by new ones. Note that the aforementioned reformer running since inception without carrying out major overhauling.

Figure 35: Sample of localized high temperature of tube surface

Since catalyst/tubes replacement is a big task and a large amount of costing is involved with these activities result in it is very hard to make proper estimation by audit team, therefore, a detailed deep dive feasibility study to be conducted in this regard.

RECOMMENDED ACTION: IMPROVEMENT IN OPERATION AND MAINTENANCE PRACTICE

This section outlines the operation and maintenance practices which can be adopted by the factory for improving efficiency and quality. We have not taken them into the analysis as we consider them to be routine activities.

ACID CLEANING OF BOILER TUBES:

The exhaust flue gas from the boiler of utility section is high as 200 deg C. Acid cleaning of boiler tubes is a process used to remove scale, deposits, and corrosion from the inner surfaces of the tubes. This cleaning method is typically employed when the boiler's efficiency is affected by the accumulation of deposits, leading to higher exhaust flue gas temperatures. After cleaning, inspect the boiler tubes to ensure that deposits have been effectively removed, and the tubes are in good condition. If necessary, additional maintenance or repairs may be carried out. Monitor the boiler's performance, including exhaust flue gas temperatures, to ensure that the cleaning has had the desired effect on efficiency.

ENERGY EFFICIENT MOTORS:

Existing motors are conventional and consume excess energy. Consultants suggest replacing those motors with latest energy efficient motors gradually. The big motors should be given the priority.

COOLING TOWER MAINTENANCE:

It has been observed that cleaning and maintenance of cooling towers is less frequent than required. There are some Leakages at cooling water pipelines. Regular maintenance will obviously improve the performance of the towers and will reduce the load on compressors.

INSTRUMENTATION:

Instrumentation in the boilers and other equipment is inadequate. A few vital instruments in these areas will certainly improve scope for better monitoring and control of process parameters. An amount of BDT 0.5 million may be spent for the instru-mentation.

ENERGY ASSESSMENT:

It is recommended by the consultants to perform energy assessment in the factory every two or three years. This practice will enable the factory management to identify new energy savings options and will help to measure achieved savings for previous energy efficient investments. In addition, regular energy assessment will provide an energy benchmark of factory's own perspective which will assist to analyze the production performance of the factory.

PREVENTIVE MAINTENANCE

Preventive maintenance is maintenance that is regularly performed on a piece of equipment to lessen the likelihood of it failing. Preventive maintenance is performed while the equipment is still working, so that it does not break down unexpectedly. It is advised by the consultants to practice preventive maintenance and plan it accordingly so that any required resources are available beforehand.

RECOMMENDED ACTION: CONDUCT DETAIL STUDY TO REPLACE THE EXISTING POWER GENERATION AND WTP SYSTEM

Replacing the existing power generation system of a fertilizer factory is a significant undertaking that requires a detailed and comprehensive study. The efficiency of the existing power generation system is much inefficient compared to modern combined cycle gas turbine power plant or gas engine generator. The co-generation efficiency may reach as high as 80%. We have studied two options to replace the power generation system. As the fertilizer industry is very old (about 37 years) and already passes the economic life, it is difficult to suggest any modification which required large investment.

Option 1: Replace the Steam turbine and generator set with modern gas engine generator. Additionally, install an exhaust gas boiler (EGB) to generate steam.

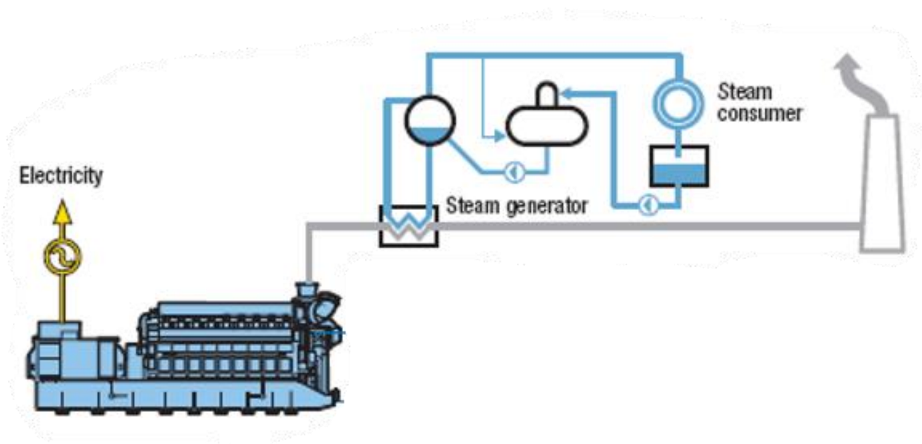


Figure 36: Gas Engine co-generation system

Option 2: Replace the whole steam and power generation system with two small size gas turbines and a heat recovery steam generator

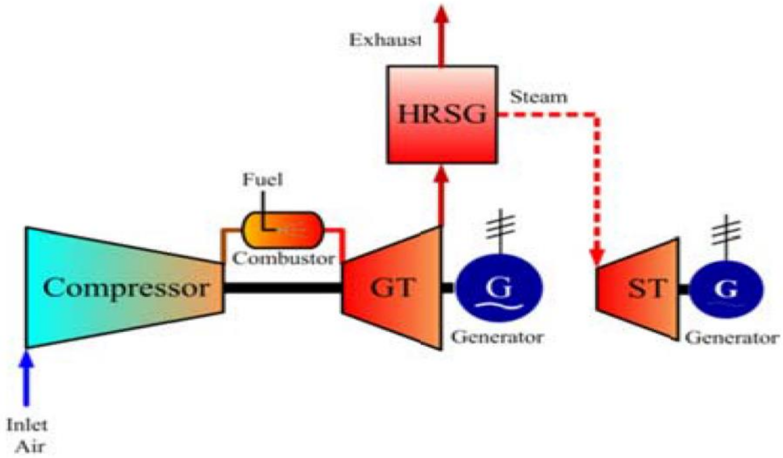


Figure 37: Gas Turbine co-generation system

In addition to power and steam generation systems, existing water treatment plant (WTP) system is also much inefficient in compared to modern RO (Reversed Osmosis) based water treatment system. Therefore, a deep dive feasibility study, both in term of technical as well as financial point of view, need to conduct.

RECOMMENDED ACTION: REPLACE THE EXISTING RESIN-BASED WATER TREATMENT SYSTEM WITH MODERN HIGHLY EFFICIENT RO (REVERSE OSMOSIS) SYSTEM.

Figure 38: RO based water treatment plant.

Perform a detailed cost-benefit analysis of the proposed power generation and WTP system. Consider capital costs, operating and maintenance expenses, fuel costs, and potential revenue streams (such as selling excess power to the grid). Evaluate the payback period and return on investment. As the river water is not available now a day in dry period and UG water quality is different from river water, this needs a detail cost analysis.

Recommended Action: Awareness program on energy efficiency

An Awareness Program on Energy Efficiency and Environmental Impact is recommended for the whole operation and maintenance teams. Factory management is recommended to develop its energy commitment and lead the energy efficiency campaign throughout the organization. An energy management team with defined role is recommended as well comprising of persons from different function. The energy management team will ensure the effective use of energy, follow-up the measures for energy conservation and take the ownership of campaign. Energy management practices to be embedded in the core functions of the organization as they are the key consumer of energy of this country.

Chapter 5: Conclusion

The energy audit conducted at Chittagong Urea Fertilizer Industry aimed to assess the current energy consumption, identify inefficiencies, and propose strategies for enhancing energy efficiency and sustainability. The audit, carried out over a week, involved a comprehensive analysis of energy systems, processes, and management practices.

The operation and maintenance team are doing a very good job keeping this 37 years old plant running. The audit team appreciates their effort and hope that they will keep doing it in more energy efficient manner. The overall steam distribution system to be improved as the losses through streamlines is very much visible and easy to optimize.

The main power generation system is running at low efficiency due to low load. An optimized load condition can lift the power generation efficiency. Factory is recommended to look into the maintenance practice as maintenance can play the leading role here for energy efficiency.

Factory management is recommended to go through the EEM suggestions, set the priority according to the operation and financial criteria andand take necessary steps. They can reach the audit team for any clarification on the report and suggestion through SREDA. The follow-up for ECM execution is vital and it is recommended to keep SREDA in loop carrying out the execution.

Considering the plant age, present energy usage scenario and other condition, the plant management is recommended to conduct a detailed cost-benefit analysis between 3 options. The options are

1. To run the plant as it is and take the energy efficiency measures as per priroty
2. To plan for major retrofitting (condenser, reformer, other) and take the energy saving measured which will give immediate benefit.
3. To plan for replacement (if that is medium to long term, take the energy efficiency measures according to priority and feasibility)

The audit team appreciates all the support received from the management, departments, and units and from every individual of the factory.

ANNEXURE: 1

STEAM TURBINE PERFORMANCE CALCULATION

Particulars	Measured Value		Unit		
	ST-1	ST-2			
Main Steam Flow	25,000.00	27,000.00	kg/h		
Main Steam Pressure	40	40	kg/cm²(g)		
Main Steam Temperature	366	366	°C		
Main Steam Enthalpy	3,130.66	3,130.66	kJ/kg		
Condensate Temperature	40	40	°C		
ST Back Pressure	738	738	mmHG(g)		
Enthalpy of Condensate Water	167.54	167.54	kJ/kg		
Generator Output	4.2	5.2	MW		
% Loading	35	43.33	%		
Enthalpy of Condensate (Sat Steam)	2,573.54	2,573.54	kJ/kg		
Avg. Feed Water Temperature	120	120	°C		
Enthaply of Feed Water	503.79	503.79	kJ/kg		
Boiler Efficiency (Indirect)	77	77	%		
NG (subsidized) Tariff	16		BDT/m³		
Lower Heating Value	35,104.72		kJ/m³		
Specific Steam Consumption	5.95	5.19	kg/kWh		
	@35% Loading	@43.3% Loading		Average	
Avg. Specific Steam Consumption	5.57		kg/kWh	5.57	kg/kWh
Avg. Standard Specific Steam Consumption	4.67	4.67	kg/kWh	4.67	kg/kWh
Turbine Heat Rate	15,636.16	13,639.54	kJ/kWh	14,637.85	kJ/kWh
Unit Heat Rate	20,306.70	17,713.69	kJ/kWh	19,010.20	kJ/kWh
Turbine Cycle Efficiency	23.02	26.39	%	24.71	%
Avg. Electricity Production Cost				**8.66**	**BDT/kWh**

EEM-1: Improvement of Combustion Efficiency of Utility Plant Boiler

Avg. Utility Boiler Efficiency (Indirect Method)	%	77.00
Lower Heating Value of NG	kJ/m³	35,104.72
NG (subsidized) Tariff	BDT/m³	16.00
Operation Time	h/yr	8,000.00
Enthalpy of Superheated Steam @ 42kg/cm², 500°C	kJ/kg	3,380.00
Enthalpy of Feed water @ 2.433kg/cm², 126°C	kJ/kg	527.56
Atmospheric Pressure	kg/cm²(a)	1.03
Correction Factor		0.60
Boiler Pressure	kg/cm²(a)	42.00
Steam Generation Capacity (rated)	kg/h	85,000.00
Steam Generation Capacity (3 Boilers)	lb/h	187,392.87

		BOILER-A	BOILER-B	BOILER-C
Current Exhaust Gas O_2 concentration	%	7.20	7.20	7.20
Corresponding Air ratio (from below Graph)		1.50	1.50	1.50
After Improvement Exhaust Gas O_2 concentration	%	3.70	3.70	3.70
Corresponding Air ratio (from below Graph)		1.20	1.20	1.20
Fuel Reduction Rate	%	3.00	3.00	3.00
Stack Temperature	°C	214.00	200.00	205.00
Current Fuel Consumption	Nm³/h	4,745.00	4,763.30	4,658.00
Current Steam Generation	kg/hr	70,800.00	70,800.00	65,300.00
Fuel Reduction	Nm³/h	142.35	142.90	139.74
Annual Fuel Saving	Nm³/yr	967,980.00	971,713.20	950,232.00
Annual Monetary Saving	BDT/yr	15.447.680.00	15.547.411.00	15,203,712.00
Total Monetary Saving from 3 Utility Boilers	BDT/yr	46,238,803.00		

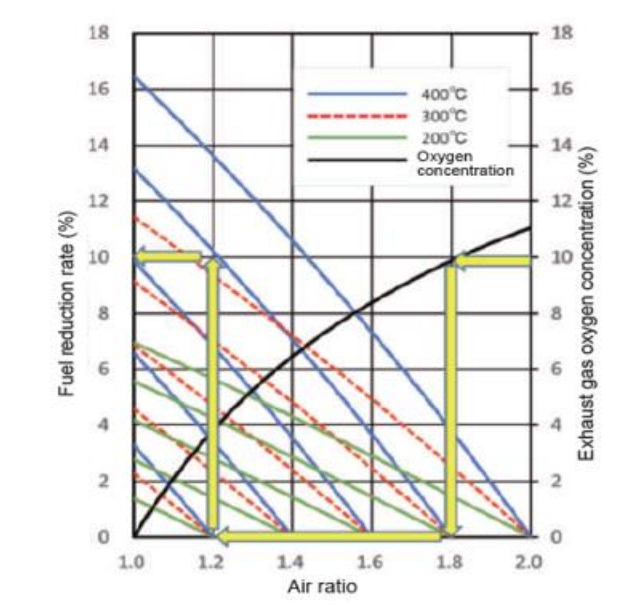


Figure: Air Ratio Reduction Effect (Energy Conservation Guidelines for Factories 2020, ECCJ)

1	Average steam production from each boiler	68.97	T/h
2	Steam Production from three boiler	206.90	T/h
3	Enthalpy of steam	3,380.00	kJ/kg
4	Gas Consumption by 3 boilers	14,166.30	m^3/h
5	Avg. Boiler Efficiency (Indirect Method)	77.00	%
6	Calorific value of gas	35,104.72	kJ/m^3
7	Average gas consumption per boiler	4,722.10	m^3/h
8	Avg. Gas saving by reducing the excess air	141.66	m^3/h
9	Annual gas saving @6800 hours operation	963,308.40	m^3/yr
10	Annual monetary savings @BDT 16/m3	15,412,934.40	BDT/yr
11	Annual monetary savings for three boilers	46,238,803.20	BDT/yr
12	Investment	1,000,000.00	BDT
13	Project lifetime	3.00	Years
14	Payback period	0.02	Year
15	IRR	4,623.84	%
16	NPV	110,057,803.33	BDT

Investment Analysis

Year	Operating Cost	Savings	Net Cash Flow (BDT)
0	-	-	-1,000,000.00
1		46,238,803.20	46,238,803.20
2		46,238,803.20	46,238,803.20
3		46,238,803.20	46,238,803.20
		NPV	110,057,803.33
		IRR	4624%

EEM-2: Energy Saving Scope by Refurbishing/ Modifying Feed Water Economizer

Avg. Utility Boiler Efficiency (Calculated by Indirect Method)			%	0.77
Lower Heating Value of NG			kJ/m³	35,104.72
NG (subsidized) Tariff			BDT/m³	16.00
Operation Time			h/yr	6800
Enthalpy of Superheated Steam @ 42kg/cm² , 500°C			kJ/kg	3,380.00
Enthalpy of Feed water @ 2.433kg/cm², 126°C			kJ/kg	527.56
Atmospheric Pressure			kg/cm² (a)	1.03
Correction Factor				0.60
Boiler Pressure			kg/cm² (a)	42.00
Steam Generation Capacity (rated)			kg/h	85,000.00
Steam Generation Capacity (rated)			lb/h	187,392.90
		BOILER-A	**BOILER-B**	**BOILER-C**
Initial stack temperature	°C	214.00	200.00	205.00
Proposed stack temperature (which is higher than dewpoint temperature of existing flue gas)	°C	90.00	90.00	90.00
Flue gas exit temperature after boiler before economizer	°C	342.00	301.00	329.00
	°F	647.60	573.80	624.20
Feed water temperature	°C	130.00	116.00	128.00
Feed Water Temperature After Economizer	°C	195.00	193.00	186.00
Temperature Increased in Economizer	°C	65.00	77.00	58.00
Feed Water Mass Flow	T/h	63.60	64.80	60.50
Enthalpy (Saturated Steam)@43.033KG/CM2	kcal/kg	759.00	759.00	759.00
Enthalpy (Saturated Steam)	Btu/lb	1,365.29	1,365.29	1,365.29
Enthalpy of Feed Water @ 130°C,116°C,128°C	kcal/kg	130.00	116.00	128.00
Enthalpy of Feed Water	Btu/lb	233.84	208.66	230.25
Boiler Heat Output	Btu/h	212,025,696.7	216,744,249.9	212,698,437.2
	MMBtu/h	212.03	216.74	212.70
Recoverable Heat (from the table by extrapolation)	MMBtu/h	28.00	28.00	28.00
Recoverable Heat	kJ/h	29,540,000.00	29,540,000.00	29,540,000.00
Currently Heat Recovered by Feed water, m X Cp X ΔT	kJ/h	17,280,120.00	20,856,528.00	14,667,620.00
Potential Additional Heat Recovery	kJ/h	12,259,880.00	8,683,472.00	14,872,380.00
Hourly Fuel Saving potential	m³/h	453.56	321.25	550.20

Annual Fuel Saving	m³/yr	3,084,174.15	2,184,469.99	3,741,391.43
Annual Monetary Saving	BDT/yr	49,346,786.47	34,951,519.81	59,862,262.94
Total Annual Monetary Saving from 3 boilers	**BDT/yr**	**144,160,569.22**		

Investment Analysis

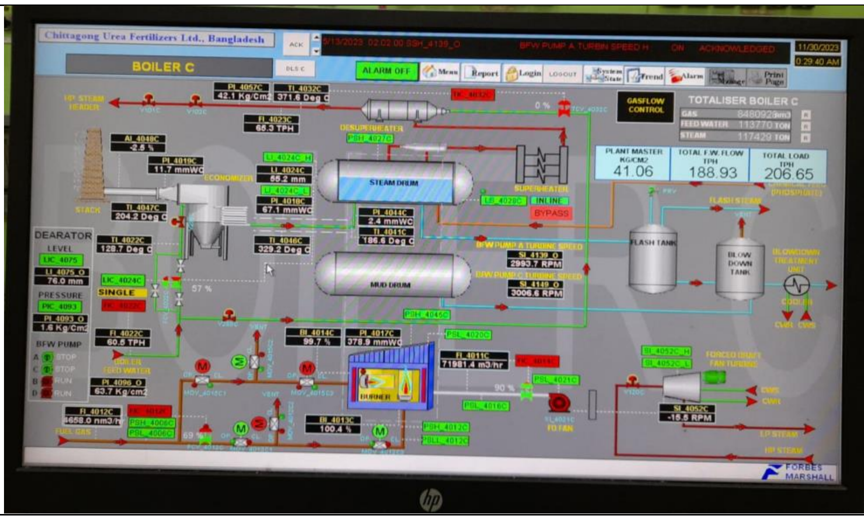
Total Heat Recovery Provision (According to Table)	88,620,000.00	kJ/h
Currently, Heat Recovered by Economizer (all 3 nos.)	52,804,268.00	kJ/h
Heat Saving Scope	35,815,732.00	kJ/h
Gas saving by refurbishing/ modifying economizer	1,325.01	m³/h
Annual gas saving @6800 hours per year operation	9,010,035.58	m³/yr
Annual monetary savings @BDT 16 per m3	144,160,569.22	BDT/yr
Investment	60,000,000.00	BDT
Project lifetime	10.00	Years
Payback period	0.42	Year
IRR	239	%
NPV	751,149,234.20	BDT

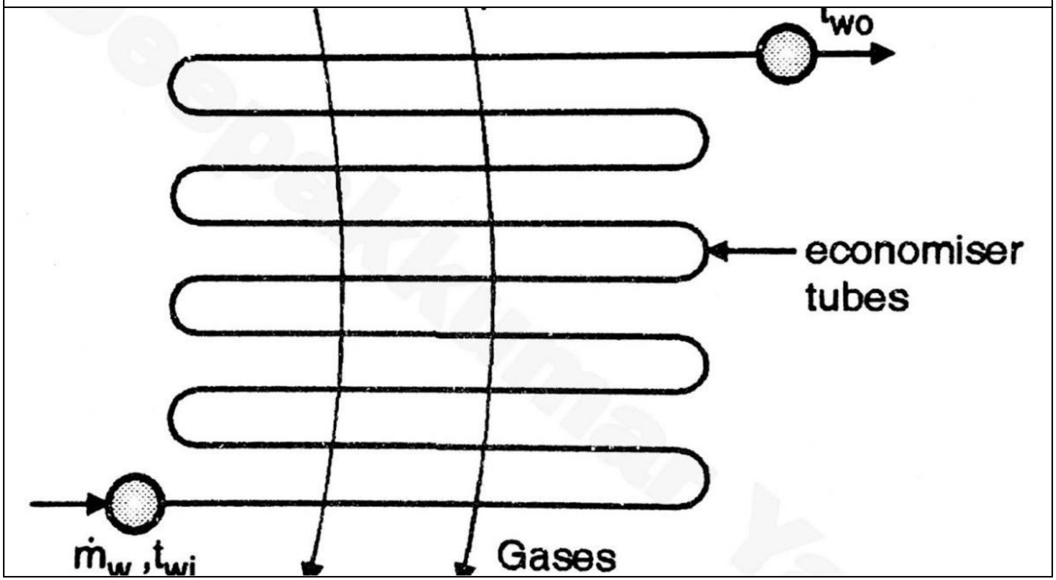
Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
0	60,000,000.00	-	-	(60,000,000.00)
1		600,000.00	144,160,569.22	143.560.569.22
2		600,000.00	144,160,569.22	143.560.569.22
3		600,000.00	144,160,569.22	143.560.569.22
4		600,000.00	144,160,569.22	143.560.569.22
5		600,000.00	144,160,569.22	143.560.569.22
6		600,000.00	144,160,569.22	143.560.569.22
7		600,000.00	144,160,569.22	143.560.569.22
8		600,000.00	144,160,569.22	143.560.569.22
9		600,000.00	144,160,569.22	143.560.569.22
10		600,000.00	144,160,569.22	143.560.569.22
			NPV	751,149,234.20
			IRR	239%

Recoverable Heat from Boiler Flue Gases

Initial Stack Gas Temperature, °F	Recoverable Heat, MMBtu/hr			
	Boiler Thermal Output, MMBtu/hr			
	25	50	100	200
400	1.3	2.6	5.3	10.6
500	2.3	4.6	9.2	18.4
600	3.3	6.5	13.0	26.1

Based on natural gas fuel, 15% excess air, and a final stack temperature of 250˚F.





EeM-3: Preheating the Polisher Water by Waste Heat from Boiler Blowdown

Avg. Utility Boiler Efficiency (Calculated by Indirect Method), η	%	0.77
Lower Heating Value of NG, LHV	kJ/m^3	35,104.72
NG (subsidized) Tariff	BDT/m^3	16
Operation Time	h/yr	6,800
Enthalpy of Superheated Steam @ $42kg/cm^2$, 500°C	kJ/kg	3,380.00
Enthalpy of Feed water @ $2.433kg/cm^2$, 126°C	kJ/kg	527.56
Atmospheric Pressure	kg/cm^2 (a)	1.03
Correction Factor		0.6
Boiler Pressure	kg/cm^2 (a)	42
Steam Generation Capacity (rated)	kg/h	85,000.00
Steam Generation Capacity (rated)	lb/h	187,392.90
Polish water flow rate	T/h	139
Polish water temperature	°C	28
Blowdown water temperature	°C	153
Avg. ambient temperature	°C	30
Blowdown water temperature after heat recovery	°C	40
Total blowdown water mass flow of 3 boilers	kg/h	3000
Recoverable heat from blowdown=m X Cp X ΔT	kJ/h	1,417,020.00
Temperature gained by polish water	°C	2.44
Fuel saving, Q/ (η X LHV)	m^3/h	52.42
Annual Fuel Saving	m^3/yr	356,474.65
Annual Monetary Saving @ $BDT16/m^3$	BDT/yr	5,703,594.10

Investment Analysis

Heat Recovery Scope by Polish Water preheat from hot blow down water	1,417,020.00	kJ/h
Gas saving by preheating polish water	52.42	m^3/h
Annual gas saving @6800 hours per year operation	419,381.94	m^3/yr
Annual monetary savings @BDT 16 per Cub. M	6,710,111.10	BDT
Investment	10,000,000.00	BDT
Project lifetime	10	Years
Payback period	1.75	Year
IRR	56	%
NPV	22,110,167.69	BDT

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
0	10,000,000.00	0	0	(10,000,000.00)
1		-	5,703,594.10	5,703,594.10
2		-	5,703,594.10	5,703,594.10
3		100,000.00	5,703,594.10	5,603,594.10
4		-	5,703,594.10	5,703,594.10
5		-	5,703,594.10	5,703,594.10
6		-	5,703,594.10	5,703,594.10
7		100,000.00	5,703,594.10	5,603,594.10
8		-	5,703,594.10	5,703,594.10
9		-	5,703,594.10	5,703,594.10
			NPV	22,110,167.69
			IRR	56%

EEM-4: Use of Boiler Blowdown Water as Cooling Tower Make-Up Water

Operation Time	h/yr	6,800.00
Cost of Cooling Tower Make-up Water (Filter Water)	BDT/L	0.1
Useful Factor (As CoC of the blowdown water is high, a portion of blowdown water is utilized at cooling tower)		0.50
Amount of Blowdown/Boiler	kg/h	500.00
Total Blowdown Amount	kg/h	1,500.00
Yearly Blowdown Amount	kg/yr	244,800,000.00
Annual Cooling Tower Make-up Saving	kg/yr	244,800,000.00
Annual Monetary Saving	BDT/yr	24,480,000.00

Investment Analysis

Annual Cooling Tower Make-up Saving	244,800,000.00	kg/yr
Annual monetary savings	24,480,000.00	BDT/yr
Investment	10,000,000.00	BDT
Project lifetime	10	Years
Payback period	0.41	Year
IRR	244.74	%
NPV	128,201,046.79	BDT

Year	Investment	Operating Cost	Savings	Net Cash Flow
-	10,000,000.00	-	-	(10,000,000.00)
1		-	24,480,000.00	24,480,000.00
2		-	24,480,000.00	24,480,000.00
3		100,000.00	24,480,000.00	24,380,000.00
4		-	24,480,000.00	24,480,000.00
5		-	24,480,000.00	24,480,000.00
6		-	24,480,000.00	24,480,000.00
7		100,000.00	24,480,000.00	24,380,000.00
8		-	24,480,000.00	24,480,000.00
9		-	24,480,000.00	24,480,000.00
10		-	24,480,000.00	24,480,000.00
			NPV (BDT)	128,201,046.79
			IRR	244.74%

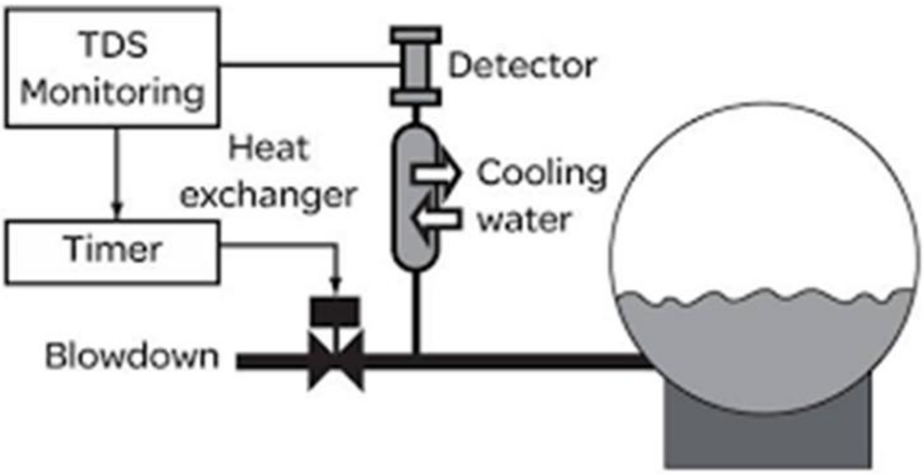
EEM-5: Minimize Boiler Blowdown by Installing Automatic Blowdown Control Valves.

Avg. Utility Boiler Efficiency (Calculated by Indirect Method), ɳ		%		77.00
Lower Heating Value of NG, LHV		kJ/m³		35,104.72
NG (Subsidized) Tariff		BDT/m³		16.00
Operation Time		h/yr		8,000.00
Enthalpy Of Superheated Steam @ 42kg/Cm², 500°C		kJ/kg		3,380.00
Enthalpy Of Feedwater @ 2.433kg/Cm², 126°C		kJ/kg		527.56
Atmospheric Pressure		kg/cm²(a)		1.03
Correction Factor				0.60
Dm Water Making Cost		BDT/L		0.33
Steam Generation Capacity		kg/h		85,000.00
Boiler Pressure		kg/cm²(a)		42.00
Boiler Temperature (Saturation)		°C		385.00
Boiler Enthalpy (Saturation)		kcal/kg		759.00
Rated Boiler Blowdown		BOILER-A	BOILER-B	BOILER-C
Rated Feedwater Flow to Drum	T/h	85.00	85.00	85.00
Current Boiler Blowdown (Manually)	T/h	0.5	0.5	0.5
% Blowdown, Current Practice	%	1.18	1.18	1.18
Currently boilers are operating, most of the time, @ 80% load but blowdown remain as rated as full load capacity.				
Feed water Flow Rate	T/h	63.80	64.80	60.50
Current Blowdown Amount	T/h	0.5	0.5	0.5
% Blowdown @Current Situation	%	0.78	0.77	0.83
% Blowdown Increase Due to Manual Operation	%	33%	31%	40%
Temperature (@ 42kg/Cm²(G))	°C	253.554	253.554	253.554
Enthalpy of water (@ 42kg/cm²(g))	kJ/kg	1,103.03	1,103.03	1,103.03
Feed water Make-Up Saving	T/h	0.25	0.24	0.29
Heat Energy Loss	kJ/h	275,108.66	262,131.84	317,932.18
Fuel Saving	m³/h	10.18	9.70	11.76
Annual Fuel Saving	m³/yr	69,208.10	65,943.57	79,981.06
Annual Monetary Saving	BDT/yr	1,107,329.62	1,055,097.09	1,279,696.96
Water And Chemical Saving	BDT/yr	559,680.00	533,280.00	646,800.00
Total Annual Saving	BDT/yr	11,667,009.62	1,588,377.09	1,926,496.96
Total Annual Saving From 3 Nos. Boilers	BDT/yr	5,181,883.67		

Investment Analysis

Energy Saving Scope	855172.6706	kJ/h
Annual energy saving @6800 hrs. year operation	5815174160	kJ/yr
Annual Natural Gas Saving	215132.7296	m^3/yr
Annual Monetary savings reducing DM water make-up	1,739,760.00	BDT/yr
Total Annual Monetary Savings	5181883.673	BDT
Investment	3000000	BDT
Project lifetime	10	Years
Payback period	0.49	Year
IRR	844.99	%
NPV	896,934,462.62	BDT

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
0	3,000,000.00	-	-	(3,000,000.00)
1		-	5,181,883.67	5,181,883.67
2		-	5,181,883.67	5,181,883.67
3		100,000.00	5,181,883.67	5,081,883.67
4		-	5,181,883.67	5,181,883.67
5		-	5,181,883.67	5,181,883.67
6		-	5,181,883.67	5,181,883.67
7		100,000.00	5,181,883.67	5,081,883.67
8		-	5,181,883.67	5,181,883.67
9		-	5,181,883.67	5,181,883.67
10		-	5,181,883.67	5,181,883.67
			NPV	26,162,385.51
			IRR	172%


TDS
Monitoring
Detector
Heat
exchanger
Cooling
water
Timer
Blowdown

EEM-6: Heat Recovery by Repairing Or Replacing Faulty Steam Traps.

Avg. Utility Boiler Efficiency, η	%	77.00
Lower Heating Value of NG, LHV	kJ/m^3	35,104.72
NG (subsidized) Tariff	BDT/m^3	16
Yearly Operation	h/yr	6800
Correction Factor		0.6
Dm Water Making Cost	BDT/L	0.33
Napier Formula : Steam flow through a sharp-edged orifice, W=0.24725 X (ΔP) X D^2		
where, W= Steam Leakage flow rate in kg/h; ΔP= Absolute Pressure Drop in bar (a), D=Diameter of Orifice in mm		
Upstream Pressure of Steam Trap	kg/cm^2(a)	5.23
	bar (a)	5.13
Saturated Steam Temperature	°C	152.00
Specific Enthalpy of Saturated Steam	kJ/kg	2,748.98
Atmospheric Pressure	kg/cm^2(a)	1.03
	bar (a)	1.01
Inner Diameter of The Orifice of Steam Trap	mm	2.0
Leakage Steam Flow Rate	kg/h	4.07
Heat Loss with leaked steam@60% passing factor	kJ/h	6719.10
	kJ/yr	45,689,859.95
Fuel Saving	m^3/h	0.25
	m^3/yr	1690.3
Monetary saving per steam trap @ 6800hr op per year	BDT/yr	27,044.79
Water And Chemical Saving@60%Passing Factor	BDT/yr	5,884.82
Total Annual Saving per steam trap	BDT/yr	32,529.60
No of Traps to replace	Nos	40
Total Annual Saving	BDT/yr	1,301,184.20

Investment Analysis

Energy Saving Scope at each steam trap (20 mm)	6,719.10	kJ/h
Annual energy saving @6800 hrs per year operation	45,689,880.00	kJ/yr
Annual Natural Gas Saving	1,690.00	m^3/yr
Annual Monetary saving for energy	27,044.79	BDT/yr
Annual Water & Chemicals Saving	5,484.82	BDT/yr
Total Annual Monetary savings per Trap	32,529.61	BDT/yr
Total Annual Monetary savings for 40 Traps	1,301,184.40	BDT/yr
Investment : 40 Traps	480,000.00	BDT
Project lifetime	5	Years
Payback period	0.37	Year
IRR	271	%
NPV	4,210,477.00	BDT

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
0	480,000	0	-	(480,000.00)
1		-	1,301,184.40	1,301,184.40
2		-	1,301,184.40	1,301,184.40
3		-	1,301,184.40	1,301,184.40
4		-	1,301,184.40	1,301,184.40
5		-	1,301,184.40	1,301,184.40
			NPV	4,210,477
			IRR	271%

EEM-7: Heat Recovery by Covering with Thick Insulation of Exposed Boiler Drum.

Parameters	Unit	Boiler-A
Boiler drum uncovered area, approx. 2.5m² dia	m²	4.91
Steam Pressure	Kg/cm2	42
Steam Temperature (Saturation)	°C	253
Steam Temperature (Saturation), converted to °F	°F	305
Drum Surface Temperature, **Before Insulation**	°C	240
Drum Surface Temperature, **After Insulation (Assumed)**	°C	60
Ambient Temperature	°C	30
Thermal Efficiency of insulation (Assumed)	%	89
Boiler Efficiency (Measured)	%	77
Operating Time	HR/YR	6800
Lower Heating Value of Fuel (NG)	kJ/m³	35,104.72
Heat Loss without Insulation (Surface tem. 240 °C)	kcal/h	4,305.00
Heat Loss with Insulation (Surface tem. 60 °C)	kcal/h	345.00
Net heat energy saving per boiler drum installing proper insulation	kcal/h	3,960.00
Total heat energy saving (3 boiler) @89% thermal insulation efficiency	kcal/h	10,573.20
Total heat energy saving (3 boiler) @89% thermal insulation efficiency, converted to kJ/h	KJ/h	44,195.98
Fuel Saving	m3/h	1.64
Annual Fuel Saving Per Boiler Drum	m3/yr	11,118.22
Annual Monetary Savings Per Boiler Drum	BDT/yr	177,891.58

Investment Analysis

Energy Saving Scope by insulating each Boiler drum	16,552.80	kJ/h
Energy Saving Scope by insulating all three boilers @ 89% thermal insulation efficiency	44,195.98	kJ/h
Annual energy saving @6800 hrs per year operation	300,532,636.80	kJ/yr
Annual Natural Gas Saving	11,118.22	m³/yr
Annual Monetary saving for energy	177,891.58	BDT/yr
Investment	300,000.00	BDT
Project lifetime	10	Years
Payback period	1.69	Year
IRR	58.71	%
NPV	705,123.00	BDT

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
-	300,000.00	-	-	(300,000.00)
1		-	177,891.00	177,891.00
2		-	177,891.00	177,891.00
3		-	177,891.00	177,891.00
4		-	177,891.00	177,891.00
5		-	177,891.00	177,891.00
6		-	177,891.00	177,891.00
7		-	177,891.00	177,891.00
8		-	177,891.00	177,891.00
9		-	177,891.00	177,891.00
10		-	177,891.00	177,891.00
			NPV	480,841.20
			IRR	72%

EEM-8: Providing Thermal Insulation of the Exposed Steam Valve & Flanges.

Valve Size (Gate, Globe, Flange)	inch	3	4	6
Steam pressure	kg/cm²	4.2	40	40
Steam temperature (saturation)	°C	152	250	250
Steam temperature (saturation)	°F	305	482	482
Thermal Insulation	%	89		
Boiler Efficiency	%	77		
Operating Time	h/yr	8600		
Lower heating value of fuel	kJ/m³	35,104.72	#REF!	
Valve/Flange Size	inch	3	4	6
Energy saving (obtained by interpolating from below chart)	Btu/h	1,710.00	6,000.00	8,500.00
Energy saving	kJ/h	1,804.05	6,330.00	8,967.50
Fuel Saving	m³/h	0.07	0.23	0.33
Annual Fuel Saving (for each valve)	m³/yr	533.93	1,873.43	2,654.03
Annual Monetary Saving	BDT/yr	8,542.84	29,974.88	42,464.41

Investment Analysis

Description	Diameter (inch)	Qty	Heat Loss (kJ/h)	Heat Loss (kJ/yr)	NG Saving Scope (m³/yr)	Monetary Saving (BDT/yr)
3-inch Valve	3	3	1,804.05	14,432,400.00	1,601.78	76,885.57
4-inch Valve	4	7	6,330.00	50,640,000.00	13,114.01	1,468,769.08
6-inch Valve	6	6	8,967.50	71,740,000.00	15,924.15	1,528,718.84
Total Saving					30,639.95	3,074,373.48
Investment						400,000
					NPV	
					IRR	

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
0	00,000	-	-	(50,000.00)
1	-	-	3074373.1	3074373.1
2	-	-	3074373.1	3074373.1
3	-	-	3074373.1	3074373.1
4	-	-	3074373.1	3074373.1
5	-	-	3074373.1	3074373.1
			NPV	10,682,426.99
			IRR	769%

Energy Savings* from Installing Removable Insulated Valve Covers, Btu/hr

Operating Temperature, °F	Valve Size, inches					
	3	4	6	8	10	12
200	800	1,090	1,560	2,200	2,900	3,300
300	1,710	2,300	3,300	4,800	6,200	7,200
400	2,900	3,400	5,800	8,300	10,800	12,500
500	4,500	6,200	9,000	13,000	16,900	19,700
600	6,700	9,100	13,300	19,200	25,200	29,300

*Based on installation of a 1-inch thick insulating pad on an ANSI 150-pound-class flanged valve with an ambient temperature of 65˚F and zero wind speed.

EEM-9: Insulating the Exposed Steam Distribution & Condensate Return Line.

Bare pipe temperature	°C	160
Ambient temperature	°C	30
Pipe temperature after insulation	°C	60
Thermal insulation	%	89
Boiler efficiency	%	80
Operating time	h/yr	6800
Lower heating value of fuel	kJ/m^3	35,104.72
NG Tarriff	BDT/ m^3	16
Heat loss before insulation[1]	$kcal/h/m^2$	9,750.00
Heat loss after insulation[2]	$kcal/h/m^2$	750.00
Heat recovery	$kcal/h/m^2$	9,000.00
	$kcal/yr/m^2$	72,000,000.00
Exposed Surface Area	sqm	60
Annual Fuel Savings	$m^3/yr/m^2$	567,835.73
Annual Monetary Saving	$BDT/yr/m^2$	9,085,371.67

Investment Analysis

Annual Heat Loss	300,960,000.00	$kJ/m^2/yr$
Fuel saving scope	567,835.73	m^3/yr
Monetary saving	9,085,371.67	BDT/yr
Investment	1,200,000	BDT
Project Period	5	yrs
Payback Period (Simple)	0.14	yrs
NPV	31,550,731.59	BDT
IRR	757	%

[1] [2]Surface Heat Loss= $\left\{10 + \frac{(Ts - Ta)}{20}\right\} X(Ts - Ta)$

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
-	1,200,000	-	-	(1,200,000)
1	-	-	9,085,371.67	9,085,371.67
2	-	-	9,085,371.67	9,085,371.67
3	-	-	9,085,371.67	9,085,371.67
4	-	-	9,085,371.67	9,085,371.67
5	-	-	9,085,371.67	9,085,371.67
			NPV	31,550,731.59
			IRR	757

EEM-10: Cleaning of Condenser (Fouling & De-scaling) of NH_3 Plant.

Lower Heating Value of NG, LHV	kJ/m³	35,104.72
NG (subsidized) Tariff	BDT/m³	16
Operation Time	h/yr	8600
Enthalpy of superheated steam@ 40kg/cm², 380°C	kJ/kg	3164
Enthalpy of feedwater@ 50°C saturation	kJ/kg	209
Atmospheric Pressure	kg/cm²(a)	1.033
Rated steam flow	kg/h	98,870.00
Correction factor		0.4
Current condenser pressure	kg/cm²(g)	-0.68
Rated condenser pressure	kg/cm²(g)	-0.90
pressure difference	kg/cm²(g)	0.22
% Back pressure increased	%	24.44
Since back pressure is increased, additional steam low is required to get the same amount of work done.		
Additional steam required @ present condition due to high back pressure in condenser	kg/h	9,667.29
Equivalent heat	kJ/h	28,566,838.67
Additional fuel required due to additional steam demand	m³/h	1,056.83
Annual fuel required	m³/yr	8,454,655.78
Annual monetary required	BDT/yr	135,274,492.46

Investment Analysis

Steam Mass Flow increase due to back pressure rise	9,667.29	kg/h
Equivalent amount of heat for addition steam flow	28,566,838.67	kJ/h
Fuel saving scope	1,056.83	m^3/h
Yearly Fuel Saving Scope @6800 hr operation per year	7,86,457.41	m^3/yr
Monetary saving per Year	114,984,318.59	BDT/yr
Investment	100,000,000.00	BDT
Simple Payback Period	0.87	Years
NPV	549,217,376.14	BDT
IRR	115	%

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
0	100,000,000.00	-		-100,000,000.00
1	-	0	114,983,318.59	114,983,318.59
2	-	0	114,983,318.59	114,983,318.59
3	-	0	114,983,318.59	114,983,318.59
4	-	0	114,983,318.59	114,983,318.59
5	-	500,000.00	114,983,318.59	114,483,318.59
6	-	0	114,983,318.59	114,983,318.59
7	-	0	114,983,318.59	114,983,318.59
8	-	0	114,983,318.59	114,983,318.59
9	-	500,000.00	114,983,318.59	114,483,318.59
10	-	0	114,983,318.59	114,983,318.59
			NPV	549,271,376.00
			IRR	135%

EEM-11: Reducing the Compressor Discharge Pressure.

Motor Capacity		243	kW
Loading Time	T_1	12172	h
Unloading Time	T_2	17048	h
% of Loading		71.40	%
Operation Time		4,000.00	h/yr
Atmospheric Pressure	P_1	1.01	bara
Current Pressure	P_2	9.41	bara
Recommended Pressure	P_3	8.01	bara
Air Flow Rate	Q	0	kg/s
Air Adiabatic Ratio	Y	1.4	
$\frac{Y-1}{Y} = \frac{1.4-1}{1.4} = 0.286$			
Shaft Power[1]		0.90	
Saving Energy Rate		9.55	%
Current Power consumption by Compressor		693,992.49	kWh/yr
Reduced Power		66,263.56	kWh/yr
Fuel Reduced		35,883.60	m^3/yr
Annual Monetary Saving		574,137.53	BDT/yr
[1]Shaft Power,			

$$\frac{B_3}{B_2} = \frac{QX\frac{Y}{Y-1}P_1V_1[\left(\frac{P_3}{P_1}\right)^{0.286} - 1]}{QX\frac{Y}{Y-1}P_1V_1[\left(\frac{P_2}{P_1}\right)^{0.286} - 1]}$$

P_2=9.41

P_3=8.01

Annual Electricity Saving	66,263.56	kWh/yr
Equivalent amount of Annual NG Saving	35,883.60	m^3/yr
Annual Monetary Saving	574,137.53	BDT/yr
Investment	0	BDT
Simple Payback Period	-	Years
NPV	-	BDT
IRR	-	%

ECM-12: Preheating condensate water extracting waste heat from NH_3 Plant Boiler Drum Blowdown Loss.

Boiler Efficiency	86	%
Reformer Efficiency	86	%
Thermal Insulation Efficiency	89	%
Lower Heating Value of NG	35,104.72	kJ/m³
NG Tariff (Subsidized)	16.00	BDT/m³
DM Water Production Cost	0.33	BDT/L
Filter Water Production Cost	0.05	BDT/L
Ambient Temperature	30	°C
Blowdown Water Flow Rate (measured)	3,200.00	kg/h
Boiler Blowdown Water Temperature (saturation)	147.00	°C
Blowdown Water Pressure	3.50	kg/cm²
Blowdown Water Enthalpy	620.00	kJ/kg
Annual Operation Time	6800.00	h/yr
Blowdown Water to be cooled up to	55.00	°C
Heat Released from Blowdown Water	1,232,652.80	kJ/h
Condensate Water Flow	99,770.00	kg/h
Condensate Water Temperature before Heating	50.00	°C
Condensate Water Temperature Rise	2.95	°C
Condensate Water Temperature Reached after Heat Gain	52.95	°C
Heat Gain by Condensate Water	1,232,652.80	kJ/h
Annual Heat Gain by Condensate Water	8,382,039,040.00	kJ/yr
Annual Fuel Saving	277,642.35	m³/yr
Annual Monetary Saving from fuel	4,442,277.63	BDT/yr
Annual Cooling Tower Make-up Saving[1]	13,056,000.00	kg/yr
Annual Monetary Saving from CT Make-up	1,305,600.00	BDT/yr
Total Annual Monetary Saving	5,747,877.63	BDT/yr
It is observed that the quality of blowdown water is quite high; therefore, it can be reused as CT make-up which will save both pumping & chemical cost of CUFL.		
Considering Reuse factor is 60%		

Investment Analysis

Annual Heat Gain by Condensate Water	8,382,039,040.00	kJ/yr
Equivalent amount of Annual NG Saving	277,642.35	m^3/yr
Annual Monetary Saving from fuel	4,442,277.63	BDT/yr
Annual Cooling Tower Make-up Saving[1]	13,056,000.00	kg/yr
Annual Monetary Saving from CT Make-up	1,305,600.00	BDT/yr
Total Annual Monetary Saving	5,747,877.63	BDT/yr
Investment	20,000,000.00	BDT
Simple Payback Period	3.48	Years
NPV	12,476,790.55	BDT
IRR	26%	%

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
0	20,000,000.00	0	0	(20,000,000.00)
1	0	0	5,747,877.63	5,747,877.63
2	0	0	5,747,877.63	5,747,877.63
3	0	0	5,747,877.63	5,747,877.63
4	0	0	5,747,877.63	5,747,877.63
5	0	0	5,747,877.63	5,747,877.63
6	0	0	5,747,877.63	5,747,877.63
7	0	0	5,747,877.63	5,747,877.63
8	0	0	5,747,877.63	5,747,877.63
9	0	0	5,747,877.63	5,747,877.63
10	0	0	5,747,877.63	5,747,877.63
			NPV	12,476,790.55
			IRR	26%

EEM-13: Installation of Automatic Blowdown Control Valve to Minimize Excessive Blowdown loss at NH3 Plant

Boiler Efficiency	86	%
Reformer Efficiency	86	%
Thermal Insulation Efficiency	89	%
Lower Heating Value of NG	35,104.72	kJ/m^3
NG Tariff (Subsidized)	16.00	BDT/m^3
DM Water Production Cost	0.33	BDT/L
Filter Water Production Cost	0.1	BDT/L
Ambient Temperature	30.00	°C
Current Blowdown Water Flow Rate	3,200.00	kg/h
Rated Blowdown Water Flow Rate	2,570.00	kg/h
Boiler Blowdown Water Temperature (saturation)	147.00	°C
Blowdown Water Pressure	3.50	kg/cm^2
Blowdown Water Enthalpy	620.00	kJ/kg
Annual Operation Time	6800.00	h/yr
Steam Generation Capacity	206,330.00	kg/h
Boiler Pressure	105.50	kg/cm^2
Boiler Temperature (Saturation)	314.00	°C
Boiler Enthalpy (Saturation)	1,425.00	kJ/kg
% Blowdown (Current)	1.55	%
Current Feed water Flow to Boiler (Calculative)	209,580.41	kg/h
% Blowdown (Rated)[1]	1.25	%
Rated Feed water Flow (Calculative)	208,932.42	kg/h
Feed water Flow Saving by Automation	648.00	kg/h
Heat Energy Loss	923,394.26	kJ/h
Annual Heat Energy Saving	6,279,080,955.24	kJ/yr
Annual Fuel Saving	207,985.05	m^3/yr
Annual Monetary Saving from fuel	3,327,760.79	BDT/yr
Annual Monetary Saving from DM Water	1,454,102.96	BDT/yr
Total Annual Monetary Saving	4,781,863.75	BDT/yr

[1] if boiler water parameters like TDS, conductivity, silica, sodium etc. can properly maintain then up to 1.25% blowdown was enough, but most of the time, it has been operating above 1.55%. Without automatic control valve, it is very tough to control steam parameter as well as blowdown water amount.

Investment Analysis

Annual Feedwater savings by automation	4,406,372.60	kg/yr
Annual Heat energy savings	6,279,080,955.24	kJ/yr
Annual Fuel Saving	207,985.05	kJ/yr
Equivalent amount of Annual NG Saving	3,327,760.79	m^3/yr
Annual Monetary Saving from DM Water	1,454,102.96	BDT/yr
Total Annual Monetary Saving	4,781,863.75	BDT/yr
Investment	4,000,000.00	BDT
Simple Payback Period	0.84	Years
NPV	24,956,549.80	BDT
IRR	122%	%

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
-	4,000,000.00	-	-	(2,000,000.00)
1	-	-	4,781,863.75	4,781,863.75
2	-	-	4,781,863.75	4,781,863.75
3	-	20,000.00	4,781,863.75	4,761,863.75
4	-	-	4,781,863.75	4,781,863.75
5	-	20,000.00	4,781,863.75	4,761,863.75
6	-	-	4,781,863.75	4,781,863.75
7	-	20,000.00	4,781,863.75	4,761,863.75
8	-	-	4,781,863.75	4,781,863.75
9	-	20,000.00	4,781,863.75	4,761,863.75
10	-		4,781,863.75	4,781,863.75
			NPV	24,956,549.80
			IRR	122%

EEM-14: Improve existing lighting systems by more energy efficient LED lamps.

		Unit / Remarks
NO-COST OPTION-1: Total Investment (Replacing existing Non-Energy Efficient bulbs with LED lamps at the end of their service life):	0.00	No investment
Average life of the existing lamps (approx.)	2.5	Yrs
Energy savings in the First year: (by replacing with the LED lamps at the end of their service life); Assumption: Number of lights to be changed per year = (Total number of lights / average life of existing lamps)	{Total annual savings with replacement of all lights / Average life of the existing lamps} = 1756204.8 / 2.5 = 702481.90	kWh
Monetary savings in the First year @ BDT 8.80 for STG	6,181,840.90	BDT
Project Lifetime	Continuous	
Payback Period	-	Immediate
NPV	-	BDT
IRR	-	%
OPTION-2: Total Investment (Replacing all existing Non-Energy Efficient bulbs):	11,222,320	BDT
Annual energy savings	1,756,205	kWh/Yr
Annual monetary savings @ BDT 8.80 for STG	15,454,602.24	BDT
Project Lifetime	5	Yrs
Payback Period	0.73	Yrs
NPV	44,488,062.37	BDT
IRR	135.82	%

Investment Analysis

Year	Investment	Saving	Net Cash Flow
0	11,222,320.00		-11,222,320.00
1		15,454,602.24	15,454,602.24
2		15,454,602.24	15,454,602.24
3		15,454,602.24	15,454,602.24
4		15,454,602.24	15,454,602.24
5		15,454,602.24	15,454,602.24
NPV (BDT)			44,488,062.37
IRR (%)			136%

EEM-15: Replacement of existing Ceiling fans by more energy efficient fans.

Description	Calculation	Unit / Remarks
Number of ceiling fans (Approx.)	5000	Pcs
Electrical load of the existing fans (weighted avg., approx.)	85	W
Operation Hours (Approx.)	{300 Days X 12 Hrs} = 3600	Hr/Yr
Cost of energy efficient (35W) ceiliing fans	6500	BDT (Govt. Rate)
Average life of the existing fans (approx.)	5	Yrs
LOW-COST OPTION: Investment (Additional investment in the First year for replacing existing fans with BLDC (35W) fans at the end of their service life)**:**	(Number of fans / 5) X (cost of BLDC fan - cost of traditional fan) = (5000 / 5) X (6500 - 3911) = **2,589,000.00**	BDT (Additional investment as compared to traditional fans)
Energy savings in the First year (by replacing with the BLDC fans at the end of their service life) Assumption: Number of fans to be replaced per year = (Total number of fans / average life of existing fans)	{(Number of fans / 5) X (Difference between Wattage) X Annual running hours}/1000 [{(5000 / 5) X (85-35) X 3600} / 1000 =**180,000**	kWh
Monetary savings in the First year @ BDT 8.80 for STG	1,584,000.00	BDT
Project Lifetime	Continuous	
Payback Period	-	Immediate
NPV	-	BDT
IRR	-	%
OPTION-2: Investment (Replacing all existing fans with energy efficient BLDC (35W) fans)**:**	Number of fans X cost of BLDC fan = 5000 X 6500 = **32,500,000.00**	BDT (Govt. Rate)
Annual energy savings	Number of fans X (Difference between Wattage) X Annual running hours / 1000 5000 X (85-35) X 3600 / 1000 **=900,000.00**	kWh/Yr
Salvage value of existing fans, BDT 200 each	1,000,000.00	
Annual monetary savings @ BDT 8.80 for STG	7,920,000.00	BDT
Project Lifetime	20	Yrs
Payback Period	4.10	Yrs
NPV	21,442,046.76	BDT
IRR	23.32	%

Investment Analysis

Year	Investment	Saving	Net Cash Flow
0	32,500,000.00	1,000,000.00	-31,500,000.00
1		7,920,000.00	7,920,000.00
2		7,920,000.00	7,920,000.00
3		7,920,000.00	7,920,000.00
4		7,920,000.00	7,920,000.00
5		7,920,000.00	7,920,000.00
6		7,920,000.00	7,920,000.00
7		7,920,000.00	7,920,000.00
8		7,920,000.00	7,920,000.00
9		7,920,000.00	7,920,000.00
10		7,920,000.00	7,920,000.00
11		7,920,000.00	7,920,000.00
12		7,920,000.00	7,920,000.00
13		7,920,000.00	7,920,000.00
14		7,920,000.00	7,920,000.00
15		7,920,000.00	7,920,000.00
NPV (BDT)			22,442,046.76
IRR (%)			23.3%

ANNEXURE 2: WATER TEST REPORTS

BOILER WATER:

FORM NO.4

RANGADIA, CHITTAGONG.
RESEARCH AND QUALITY CONTROL LABORATORY

DAILY ANALYTICAL REPORT

PLANT : UTILITY

DATE 20.11.23

SAMPLE \ ITEM	TIME HRS.	pH	COND. uS/cm	TURB. DEGREE	SiO_2 ppm	R - Cl_2 ppm	M - AlK ppm	CA - H ppm	Cl – ppm	Fe ppm
DESIGN VALUE		7 - 8	230	46	15.0	–	64	32	15	2
RAW WATER	0700	7.15	120.0	74.87	10.94				9.70	
	1500	7.44	129.02	96.02		9	52.0	32.30	8.29	
	2300									
DESIGN VALUE		6 - 8		20 (msx)	–	0.5	–	–	–	–
CLARIFER OUT	0700	7.20	—	6.42						
	1500	6.82		2.76						
	2300									
DESIGN VALUE		6 - 8		20 (msx)	–	0.5	–	–	–	–
SNAD FILTER OUT	0700			1.30		PH	Cond.	Turb.	SiO_2	Cl⁻
	1500			0.71	F/W	6.90	166.0	1.19	16.94	16.48
	2300									
DESIGN VALUE		6.5 - 8		20 (msx)	–	0.5	–	–	–	–
POTABLE WATER (A)	0700	7.10	1.10		0.003					
	1500									
	2300	6.85	1.0		0.008					
DESIGN VALUE		7 - 8	230	–	10	–	64	–	15	–
A.C. FILTER (A) OUT	0700	7.40	1.[illegible]		0.002					
	1500									
	2300	6.70	1.0		0.004					
DESIGN VALUE		6 - 7	0.3	–	2	–	–	–	–	–
ANION (B) OUT	0700	7.5	1.07		0.003					
	1500	7.75	0.90		0.004					
	2300	7.2	1.0		0.003					
DESIGN VALUE		7 - 8	0.3	–	0.02	–	–	–	–	0.02
POLISHER (B) OUT	0700	7.20	1.10		0.002					
	1500	7.46	0.90		0.002					
	2300	7.3	0.90		0.002					
DESIGN VALUE	[illegible]	7.80	1.90	–	0.003	0.3	–	–	–	–
POTABLE WATER (H)	1500	7.52	1.00		0.002					
	2300	7.00	1.00		0.002					

SAMPLE \ ITEM	TIME HRS.	pH	COND uS/cm	SiO_2 ppm	N_2H_4 ppm	PO_3. ppm	Oxygen ppm
DESIGN VALUE		8 - 9.5	5	0.2	0.07(Max)	–	0.07(Max)
DEAERATOR	[illegible]	8.80	5.00	0.01	0.059		
	1500	8.84	5.70	0.01	0.04		
	2300	8.82	4.7	0.01	0.05		
DESIGN VALUE		9.5 - 11	800	20	–	5 - 15	–
BOILER A	[illegible]	9.45	[illegible]	0.76		11.00	
	1500	9.60	41.0	0.32		9.50	
	2300	9.25	35.2	0.53		8.95	
DESIGN VALUE		9.5 - 11	800	20	–	5 - 15	–
BOILER B	[illegible]	9.40	37.0	0.36		8.20	
	1500	9.50	33.00	0.21		7.34	
	2300	9.22	28.5	0.37		6.67	
DESIGN VALUE		9.5 - 11	800	20	–	5 - 15	–
BOILER C	[illegible]	9.60	213.2	0.40		10.34	
	1500	9.70	42.0	0.23		9.42	
	2300	9.45	33.0	0.43		8.23	
DESIGN VALUE		–	10	0.5	–	–	–
POLISHER IN - LET	[illegible]	8.60	4.20	0.004			
	1500	8.80	5.40	0.004			
	2300	8.65	4.8	0.003			
DESIGN VALUE		7 - 8	0.3	0.02	–	–	–
POLISHER OUT - LET (A)	[illegible]	7.30	1.[illegible]	0.002			
	1500	7.38	0.90	0.002			
	2300	6.90	1.0	0.001			
DESIGN VALUE	[illegible]	CO_2% - 10			O_2% - 1.8 - 2.5		
BOILER FLUE GAS							
SHIFT	SHIFT - IN - CHARGE				LAB - IN - CHARGE		
MORNING	[illegible] 20.11.23						
EVENING	[illegible] 20.11.2023						
NIGHT	[illegible] 20.11.23						

COOLING WATER:

Chittagong Urea Fertilizer Ltd.
Rangadia, Chittagong
Laboratory / Technical Services

Date:23/11/23

Subject :- Weekly Cooling water complete analysis result.

Date of Analysis : 22/11/23

SL. NO.	Description / Item	Unit	Design Value	Analysis Result: Ammonia C.W	Urea C.W	Utility C.W	Make up Water
01.	Temperature	°C	33°C	30	29	29	30
02.	pH		7.0-9.0	7.60	9.0	7.0	7.32
03.	Conductivity	µS/Cm	<2000	854.0	1380.0	706.0	147.0
04.	Turbidity	Degre	<20	9.52	3.69	1.67	0.83
05.	Silica (as SiO_2)	ppm	<120	38.03	21.34	25.26	10.06
06.	Total Phosphate (PO_4^{-3})	ppm	0-12	3.21	2.80	3.13	—
07.	Chloride (as Cl^-)	ppm	<200	72.20	140.0	110.0	12.80
08.	M-Alkalinity (as $CaCO_3$)	ppm	30-40	24.0	460.0	14.0	38.0
09.	Ca- Hardness (as $CaCO_3$)	ppm	50-300	112.20	57.20	72.20	32.20
10.	Ammonia (as NH_4^+)	ppm	-	32.33	251.18	8.12	—
11.	Nitrite (as NO_2^-)	ppm	0.2	1.90	46.87	63.20	—
12.	Nitrate (as N)	ppm	10	10.41	9.80	14.95	—
13.	Sulphate (as SO_4^{-2})	ppm	100	77.63	36.06	52.26	20.17
14.	Total Iron (as Fe)	ppm	2	0.31	0.05	0.06	0.06
15.	Total Solid	ppm	170-1500	425.0	650.0	335.0	—
16.	Chemical Oxygen demand (COD)	ppm	10	8.56	55.08	24.88	0.81
17.	Cycles of concentration		[illegible]-7	3.55	1.85	2.30	—
18.	Stability Index		6-7	9.04	5.72	6.98	—
19.	$R-Cl_2$	ppm	0.5-1.0	0.10	0.80	0.50	—

23.11.23 — **Analyst**

23.11.23 — **Supervised by**

23/11/23 — **Laboratory-In-charge**

C.C.TO :-
01. General Manager (Operation), CUFL.
02. Plant in Charge, Ammonia / Urea / Utility, CUFL.
03. Office Copy.

Chittagong Urea Fertilizer Ltd.
Rangadia, Chittagong
Laboratory / Technical Services

Date: 16/11/23

Subject :- Weekly Cooling water complete analysis result.

ate of Analysis : 15/11/23

.. O.	Description / Item	Unit	Design Value	Analysis Result			
				Ammonia C.W	Urea C.W	Utility C.W	Make up Water
1.	Temperature	°C	33°C	30	25	26	30
2.	pH		7.0-9.0	7.34	9.03	7.25	7.58
3.	Conductivity	µS/Cm	<2000	636.0	943.0	551.0	160.0
4.	Turbidity	Degre	<20	5.70	3.69	4.40	0.95
5.	Silica (as SiO_2)	ppm	<120	24.44	17.84	22.10	8.99
6.	Total Phosphate (PO_4^{-3})	ppm	0-12	2.77	2.11	2.27	—
7.	Chloride (as Cl^-)	ppm	<200	70.20	60.80	118.0	18.80
8.	M-Alkalinity (as $CaCO_3$)	ppm	30-40	16.0	590.0	24.0	30.20
9.	Ca- Hardness (as $CaCO_3$)	ppm	50-300	32.0	80.0	89.0	34.80
0.	Ammonia (as NH_4^+)	ppm	-	24.87	136.95	8.62	—
.	Nitrite (as NO_2^-)	ppm	0.2	7.22	15.26	20.35	—
.	Nitrate (as N)	ppm	10	10.30	2.85	9.82	—
.	Sulphate (as SO_4^{-2})	ppm	100	64.80	44.93	38.20	22.92
.	Total Iron (as Fe)	ppm	2	0.14	0.08	0.04	0.17
.	Total Solid	ppm	170-1500	315.0	470.0	275.0	—
.	Chemical Oxygen demand (COD)	ppm	10	10.12	22.0	25.32	1.32
.	Cycles of concentration		4-7	1.28	2.23	2.53	—
.	Stability Index		6-7	10.68	5.33	9.71	—
.	R-Cl_2	ppm	0.5-1.0	6.20	0.40	0.60	—

16.11.23   16-11-23   16.11.23

.nalyst   Supervised by   Laboratory-In-charge

C.TO :-
01. General Manager (Operation), CUFL.
02. Plant in Charge, **Ammonia / Urea / Utility** CUFL.
03. Office Copy.

ANNEXURE 3: RULE OF THUMB (ROT) USED IN ANALYSIS

1. 1% gas can be saved for every 20°C rise of air temperature.
2. 1 Kg of natural gas requires 17 kg of air for combustion. If we include 5% of excess air, itshould be 17.85 Kg air for burning properly 1 kg of natural gas.
3. The conversion efficiency of heat exchanges (Economizer, air pre-heaters, recuperatoretc. is 60-65%)
4. Replacement of T8 light by T5 lights saves Energy by 25%.
5. Heat rate of waste heat recovery power plant is 4,000 Kcal/kWh.
6. The cost of waste heat recovery power plant is 100 million BDT/MW
7. Pl. add one BDT/kWh towards capital cost, financing charge, O & M etc. whilecalculating cost of kWh generation from gas generators.
8. In a compressor reduction of one discharge pressure by one kg/cm^2 normally savespower by 9-10 %.
9. 1 Ton AC requires 3,000 kcal /hr.
10. Increase in feed water temp by 6°C reduces fuel consumption by 1%.
11. 10% reduction in excess air improves Boiler efficiency by 1%.
12. Waste Heat Boiler (WHB) produces 500 kg steam per 1,000 kW heat input.
13. Insulation cost is BDT 10,000 per square meter for HVAC system.
14. Cost of high efficiency motor with inverter is BDT 2,200 per kW power rating.
15. Cost of VFD/Inverter is BDT 10,000 per kW power rating.
16. Energy management can save up to 2% of the overall energy consumed by the plant.
17. Every 1°C increase in the set temperature of air conditioner reduces the powerconsumption by 3%
18. Every one percent reduction in oxygen in flue gas will reduce gas consumption by 1%
19. Every 1 bar reduction in compressed air pressure reduces the power consumption by 8%

ANNEXURE 4: PORTABLE INSTRUMENTS USED FOR MEASUREMENTS

No	Description	Manufacturer	Model Name	Quantity
1	Ultrasonic Flow Meter	Endress Hauser	Prosonic DMTF (M+L)	01 set
2	Thermo-Hygrometer	TESTO	TESTO 625	01 pc
3	Combustion Air Analyzer	TESTO	TESTO 320	01 set
4	Infrared Temperature Meter	KIMO	KIRAY100	01 pc
5	Power Quality Analyzer	HIOKI	PW3198	01 set
6	Thermal Imaging Camera	FLIR	C8940	01 pc
7	Thermometer (Digital) with Surface Probe	TESTO	TESTO 925	01 set
8	Lux Meter	HIOKI	FT3424	01 pc
9	Thermo- Anemometer	CEM	DT-618	1 set
10	AC Clamp current meter	HIOKI	CM3280-10F	01 pc

ANNEXURE 5: TECHNICAL SPECIFICATION OF MAJOR EQUIPMENT

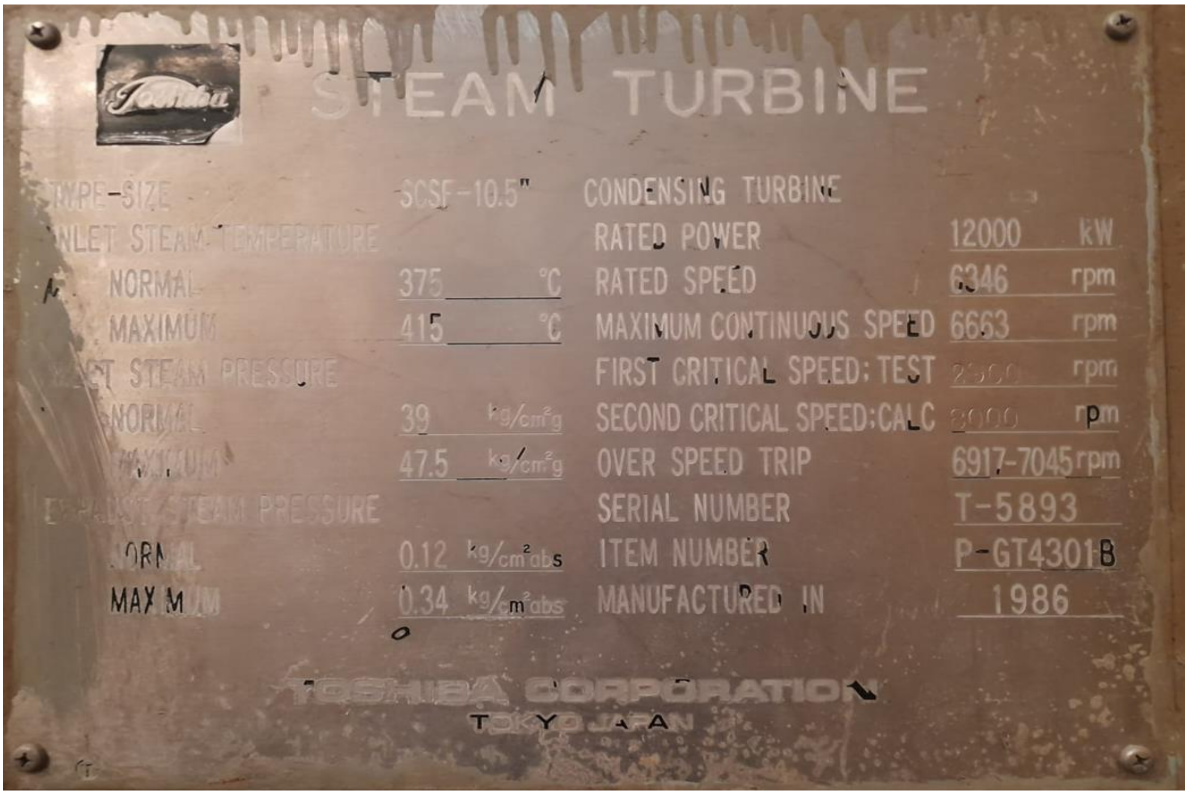


Figure: Steam turbine technical datasheet.

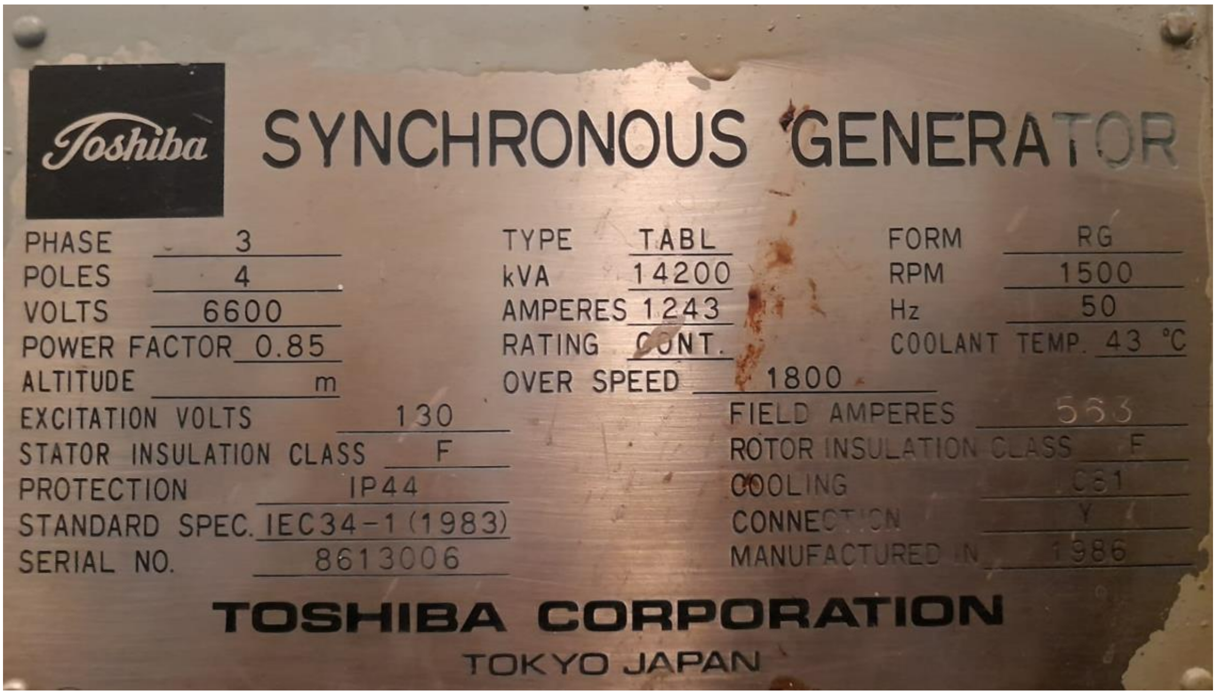


Figure: Steam turbine generator technical datasheet.

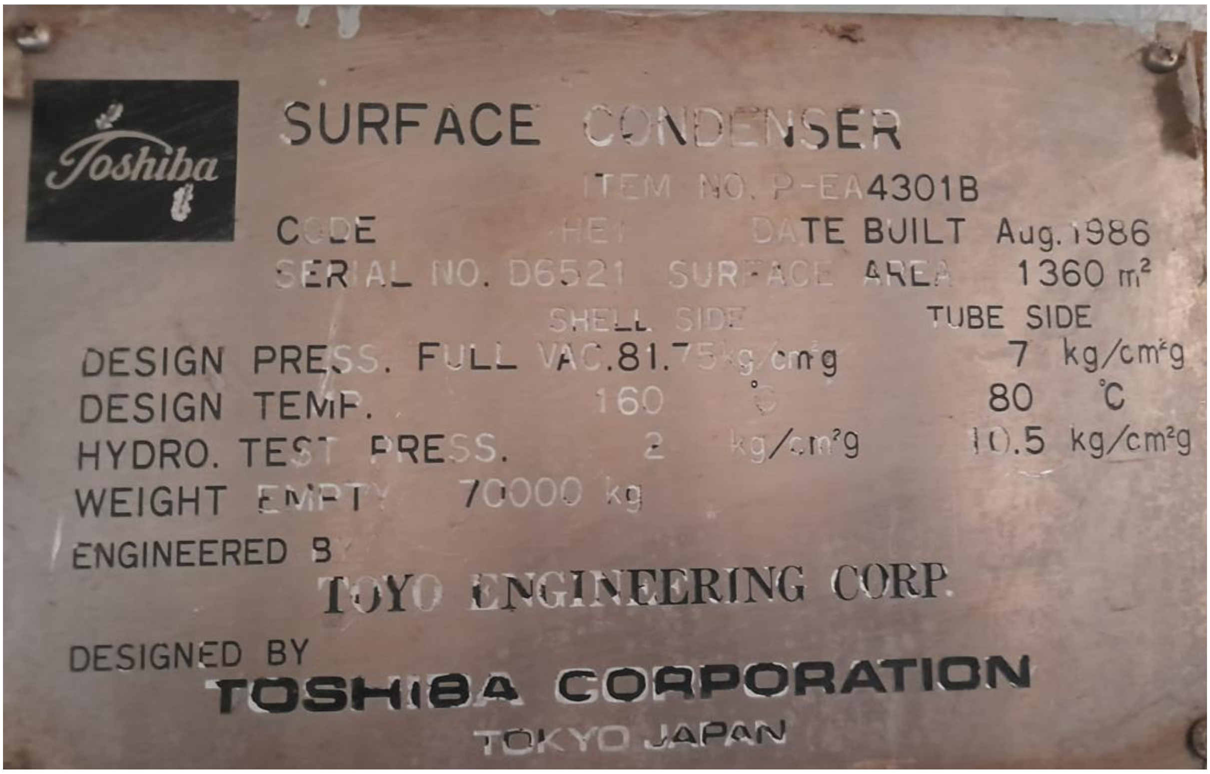


Figure: Steam turbine condenser technical datasheet.

Figure: Steam turbine gland steam condenser technical datasheet.

Figure: Steam turbine ejector technical datasheet.

Figure: Condensate Pump technical datasheet.

Figure: Liquid N_2 Storage Tank technical datasheet.

Figure: Utility Air compressor technical datasheet.

ANNEXURE 6: PROCESS FLOW DIAGRAM

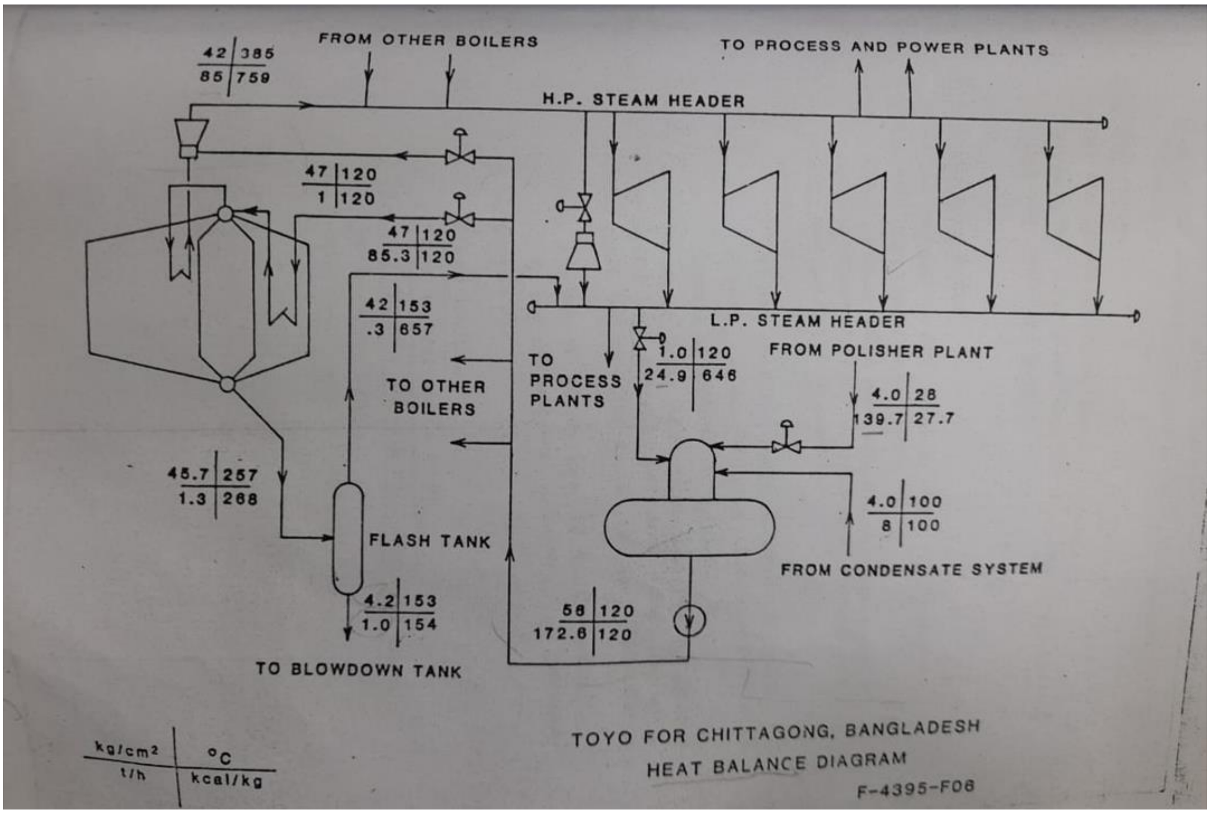


Figure: Heat balance diagram of utility boiler

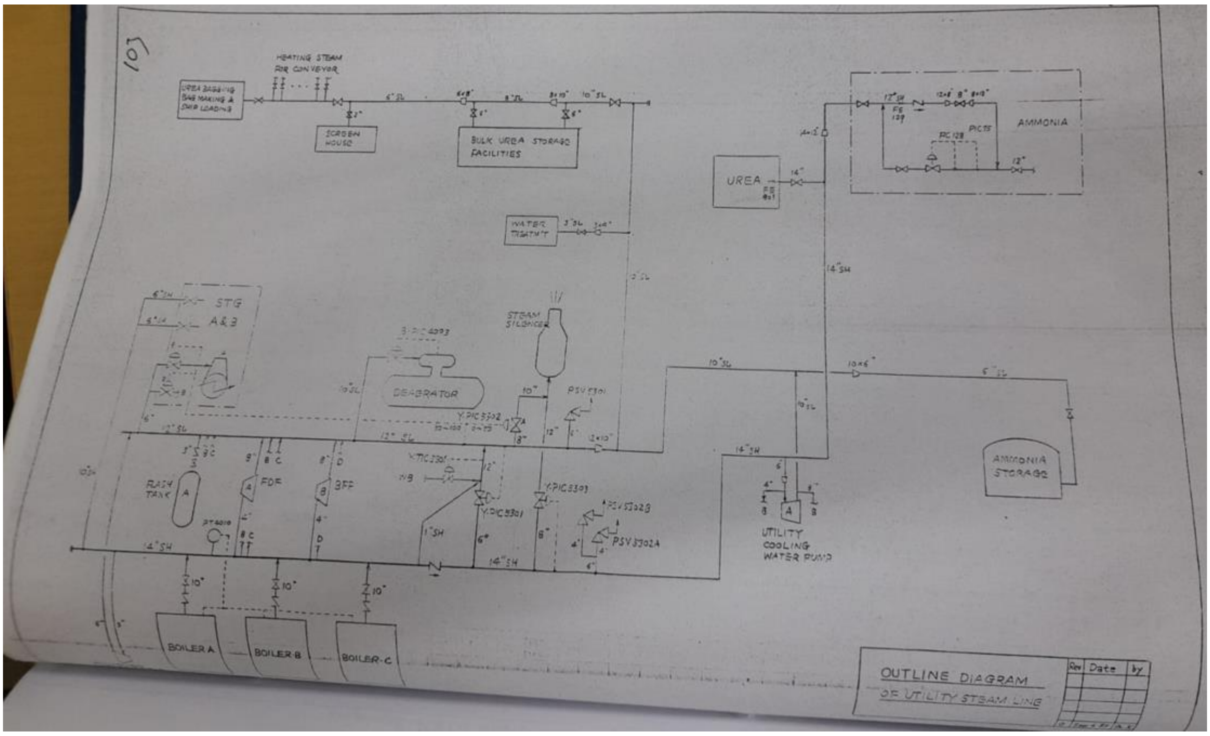


Figure: Outline diagram of Utility Steam System

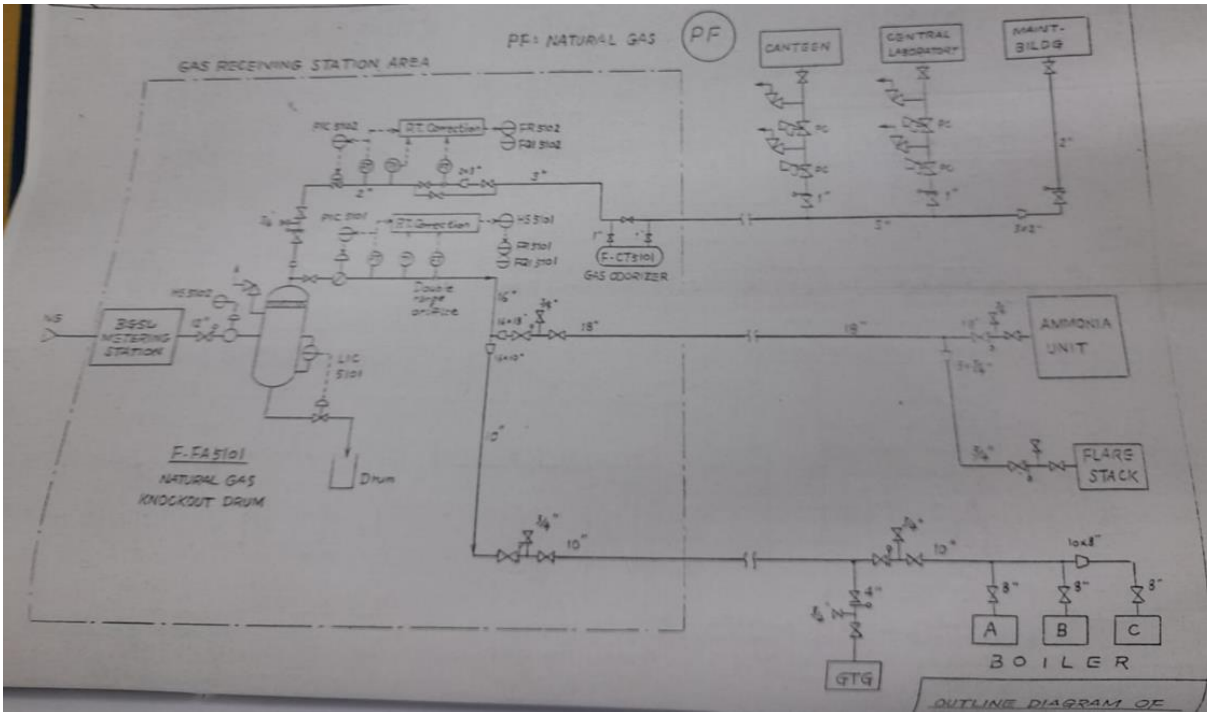


Figure: Outline diagram of Natural Gas System

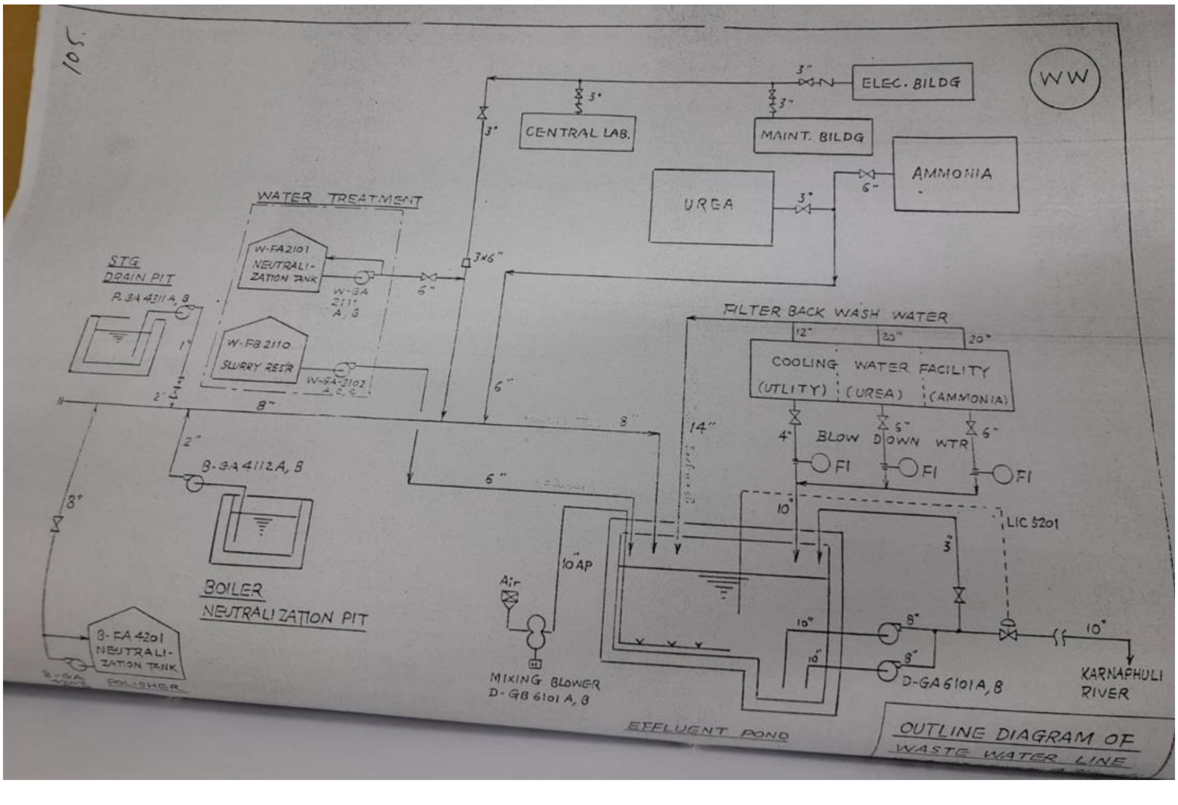


Figure: Outline diagram of Wastewater System

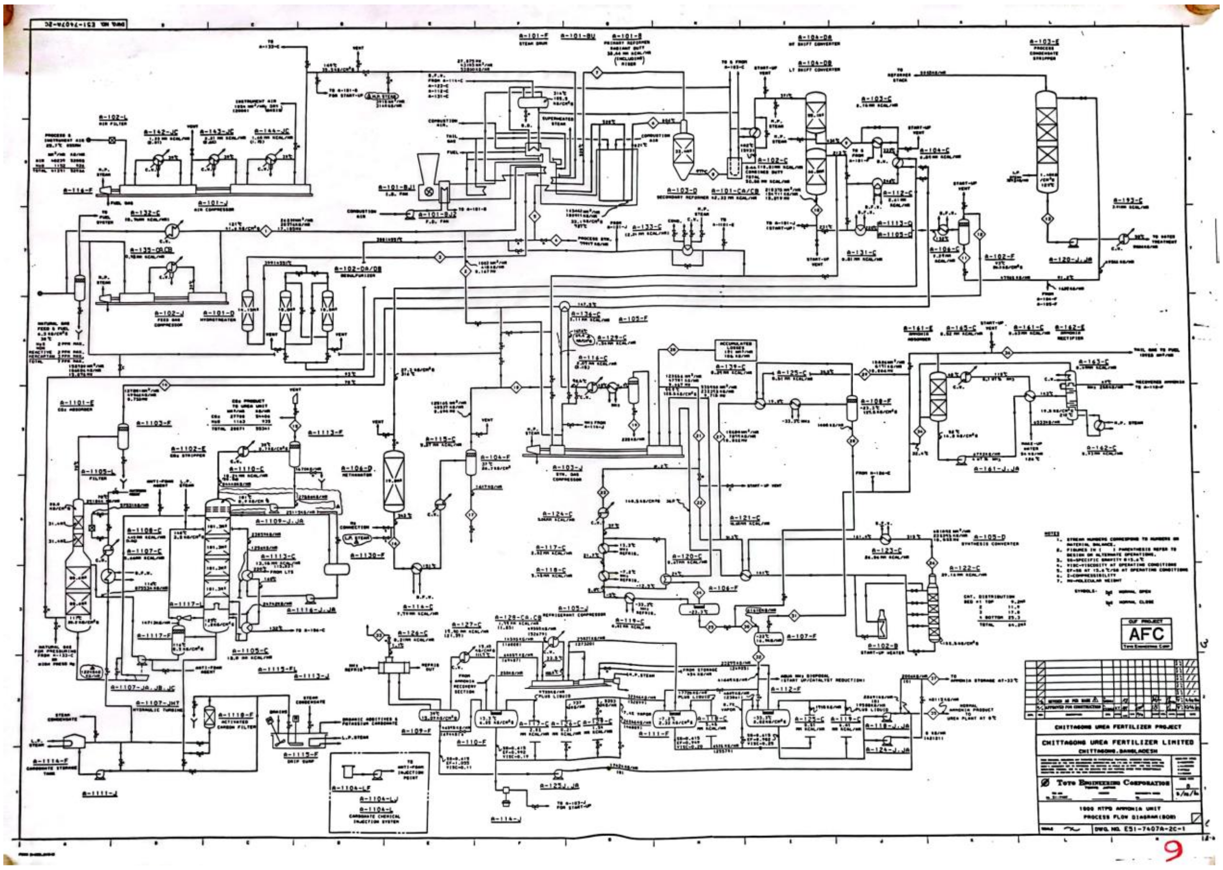


Figure: Process flow diagram of NH_3 Plant

Annexure 7: Single Line Diagram

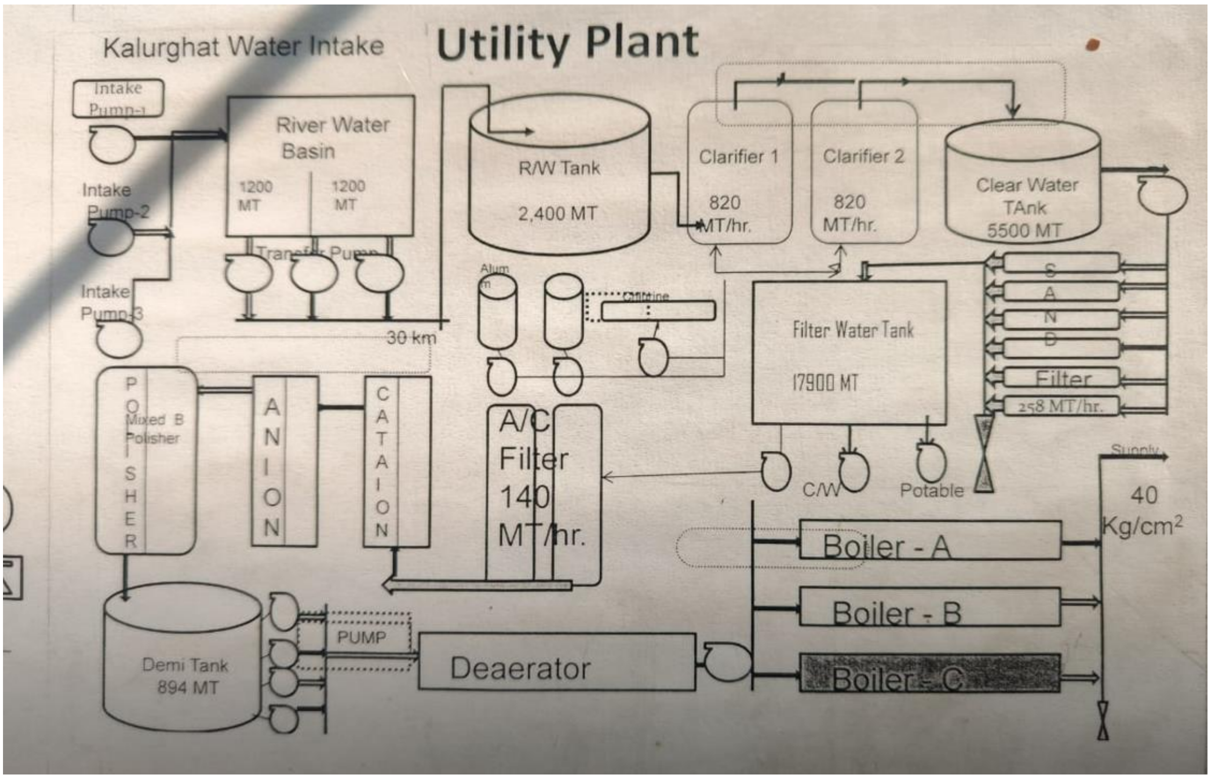


Figure: Block diagram of utility plant.

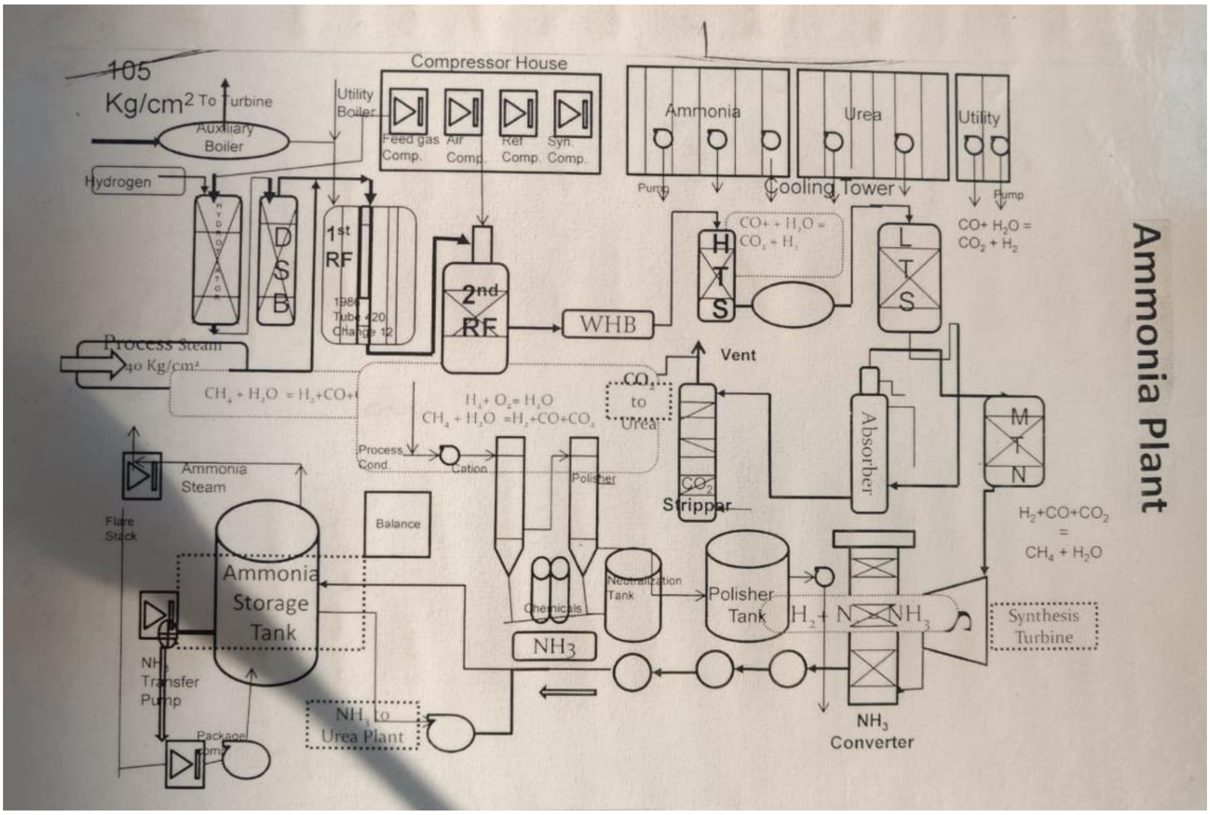


Figure: Single line diagram of Ammonia plant.

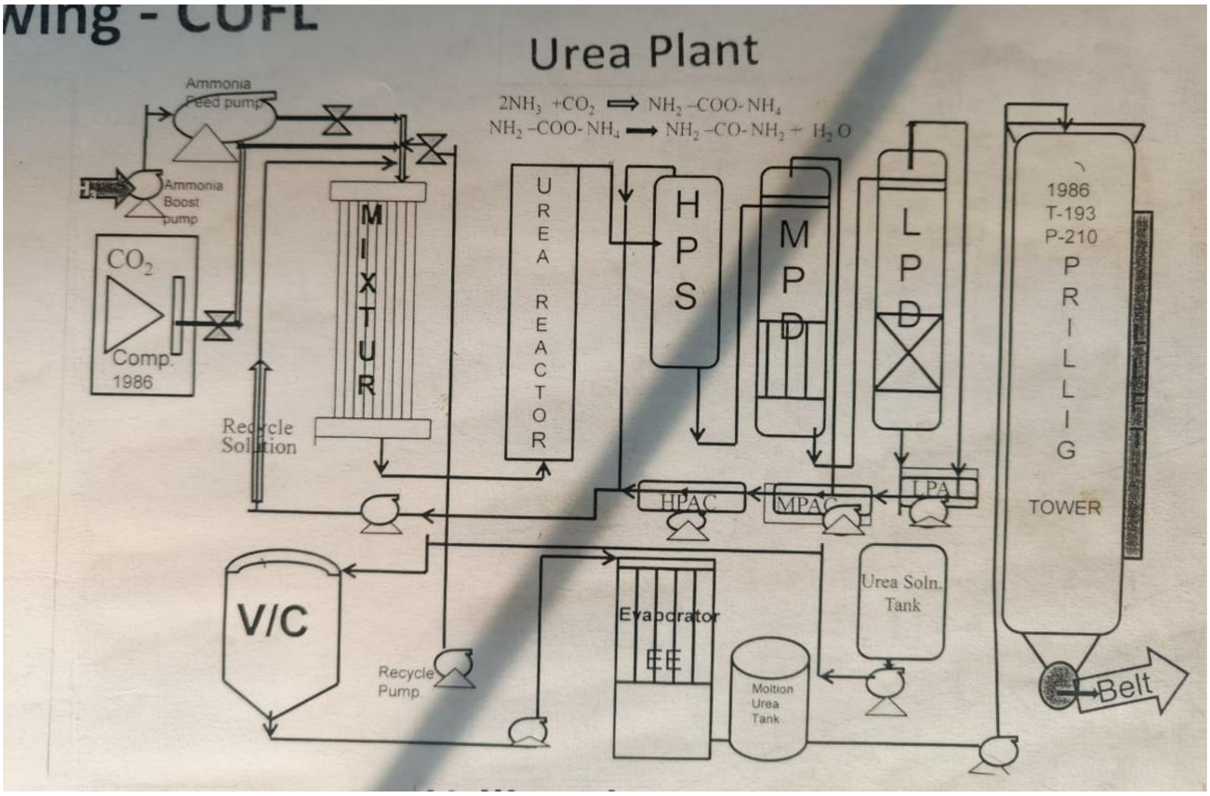


Figure: Single line diagram of Urea plant.

Annex C

Energy Audit Reports of AFCCL

Energy Audit Report

of

Ashuganj Fertilizer & Chemical Company Limited

Ashuganj, Brahmanbaria, Bangladesh

Prepared by

SUSTAINABLE AND RENEWABLE ENERGY DEVELOPMENT AUTHORITY (SREDA)

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Acknowledgement

The Sustainable and Renewable Energy Development Authority (SREDA) would like to extend its heartfelt appreciation to the senior management team and all officials of Ashuganj Fertilizer and Chemical Company Limited (AFCCL) for providing us with the valuable opportunity to conduct a comprehensive energy audit at their facility. We are deeply grateful for the trust and cooperation extended to us throughout this process.

We would also like to specifically acknowledge the dedicated technical staff at AFCCL for their exceptional support and assistance during the audit. Their prompt responsiveness in providing the necessary data, insights, and access to key systems was crucial in ensuring the smooth and efficient execution of the audit. Without their collaboration, the process would not have been as seamless or effective.

In addition, we would like to express our gratitude for the engaging and constructive discussions we had during our visits. The openness and willingness to share knowledge and perspectives made the audit experience not only productive but also highly enjoyable. The supportive environment created by the AFCCL team, coupled with their genuine interest in the outcomes of the audit, contributed significantly to its success.

Finally, we want to emphasize that the success of this audit would not have been possible without the collective efforts of everyone involved. The teamwork, professionalism, and collaborative spirit demonstrated by the entire AFCCL team played a vital role in making this energy audit a meaningful and fruitful endeavor. We look forward to continuing our partnership with AFCCL in the future and supporting their efforts toward sustainable energy practices.

DISCLAIMER

This Energy Audit Report has been prepared by a team of certified energy auditors, selected jointly by the Sustainable and Renewable Energy Development Authority (SREDA) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The primary objective of this report is to assess and analyse the energy consumption and efficiency of Ashuganj Fertilizer and Chemical Company Limited (AFCCL), based on the data collected during the audit process.

The energy audit was conducted in accordance with established industry standards and best practices. The assessment includes a comprehensive review of key facilities within the AFCCL site, including the Ammonia Plant, Urea Plant, Utility Section, and Water Treatment Process. The audit team has analysed the energy consumption patterns across the entire facility to identify areas for potential improvement.

The findings and recommendations presented in this report are based on the information available at the time of the audit. It is important to note that the accuracy and relevance of the audit results depend on the data provided by the client and the conditions observed during the site visit. Changes in factors such as equipment usage, occupancy, operational practices, and external influences may impact the actual energy performance of the facility. Therefore, the recommendations made in this report are based on the current conditions and assumptions, and may need to be reassessed if there are significant changes in the facility's operations or equipment.

Neither SREDA, GIZ, nor any of their representatives can be held liable for any direct, indirect, incidental, consequential, or special damages, losses, or expenses resulting from the use of or reliance on the information provided in this report.

The responsibility for implementing the recommendations outlined in this report rests solely with Ashuganj Fertilizer and Chemical Company Limited. SREDA, GIZ and the audit team are not liable for any decisions or actions taken by the client based on the findings of this audit. This report has been provided in good faith, and every effort has been made to ensure its accuracy.

Note: If you have any queries regarding this report, please contact us within three months from the date of issuance.

Abbreviation

AC	Alternating Current
CO	Carbon Mono Oxide
CO_2	Carbon Dioxide
AFCCL	Ashuganj Fertilizer & Chemical Company Limited
DC	Direct Current
DG	Diesel Generator
ECM	Energy Conservation Measures
EMS	Energy Management System
GCV	Gross Calorific Value
GEG	Gas Engine Generator
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GJ	Gigajoule
HC	Hydrocarbons
IRR	Internal Rate of Return
Kg	Kilogram
KJ	Kilojoule
kW	Kilowatt
kWh	Kilowatt Hour
m^3	Cubic Meter
MJ	Mega-joule
MT	Metric Ton
NG	Natural Gas
NPV	Net Present Value
O&M	Operation and Maintenance
PF	Power Factor
PLC	Programmable Logic Controller
RH	Relative Humidity
SEC	Specific Energy Consumption
SREDA	Sustainable and Renewable Energy Development Authority
VFD	Variable Frequency Drive
WHR	Waste Heat Recovery

CONVERSION FACTORS

1 kWh of electricity	3.6	MJ
$1m^3$ Natural Gas	38.77[5]	MJ
1Litre of Diesel	36.00	MJ
$1m^3$	0.035	mcf
Specific Heat of Air	0.25	kcal/kg °C
Specific Heat of Flue Gas	0.23	kcal/kg °C
1 Cal	4.187	J
1 GJ of Natural Gas emits	55	kg of CO2
1 GJ of Grid Electricity emits	180[1]	kg of CO2
Energy Tariff		
Gas (Captive Power)	16	BDT/m^3
Gas (Industry)	16	BDT/m^3
Electricity	8.8	BDT/ kWh
Exchange Rate		
1 USD	115	BDT

[5] National Energy Balance 2021-22, SREDA

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EXECUTIVE SUMMARY

Enhancing energy efficiency is recognized as the swiftest and most economical approach to tackling issues related to energy security, the environment, and the economy. Improvements in energy efficiency involve lowering the energy consumption associated with a specific service or level of activity.

The factory's total energy consumption was assessed, revealing the relation between the annual production and the specific energy consumption. This includes natural gas as feed, natural gas as fuel and other energy sources. The energy-intensive urea production process was scrutinized. Opportunities for optimizing equipment efficiency and streamlining operational procedures were identified, potentially reducing energy consumption.

Ammonia Production and Specific Energy Consumption:

Table 27: Energy Consumption Benchmark for Ammonia Production

Financial Year	Ammonia Production (MT)	Specific Energy Consumption (GJ/Ton)	Specific Gas Consumption (mcf/Ton)
2018-2019 to 2022-2023	430,315	135.53	122.35

1. Urea Production and Specific Energy Consumption:

Table 28: Energy Consumption Benchmark for Urea Production

Financial Year	Urea Production (MT)	Specific Energy Consumption (GJ/Ton)	Specific Gas Consumption (mcf/Ton)
2018-2019 to 2022-2023	727,073	80.21	72.41

Table 29: Break Down of Energy Consumption for Ammonia (from july2018 to June 2023)

FY	Ammonia Production (MT)	Total Gas Consumption (M3)	Specific Energy Consumption (GJ/Ton)	Specific Gas Consumption (MCF/Ton)
2018-2019	89165	268274719	116.65	105.31
2019-2020	107182	375286928	135.75	122.55
2020-2021	85187	375910939	171.08	154.45
2021-2022	56745	209007097	142.80	128.91
2022-2023	92036	275785375	116.17	104.88
Total	**430315**	**1504265058**	**135.53**	**122.35**

Table 30: Break Down of Energy Consumption for Urea (from july2018 to June 2023)

FY	Urea Production (MT)	Total Gas Consumption (M3)	Specific Energy Consumption (GJ/Ton)	Specific Gas Consumption (MCF/Ton)
2018-2019	150057	268274719	69.31	62.57
2019-2020	180993	375286928	80.39	72.57
2020-2021	142557	375910939	102.23	92.29
2021-2022	96046	209007097	84.37	76.16
2022-2023	157420	275785375	67.92	61.32
Total	**727073**	**1504265058**	**80.21**	**72.41**

ENERGY CONSERVATION MEASURES (ECMs)

Table 31: Energy Conservation Measures

SL No.	Energy Conservation Measures (ECM)	Investment Cost		Annual Savings						% share of Identified Savings	Payback Period
		BDT	USD	NG (m³)	Electricity in kWh	GJ	TOE	t-CO2 (MT/yr)	BDT	BDT	Years
1	Minimize Boiler Blowdown by Installing Automatic Blowdown Control Valves.	4,000,000	34,783	744,571	-	28,867	689	1,664	812,000	0.75	4.93
2	Boiler Blow Down Water Use as Cooling Tower Make-Up Water	2,000,000	17,391	-	-	-	-	-	484,500	0.45	4.13
3	Energy Saving Opportunities from Uninsulated Pipeline (calculation based on 1m2 surface area)	9,200	80	1,965	-	76	2	14	31,440	0.03	0.29
4	Energy Saving Opportunities from Cooling & Water Intake pumps	11,025,000	95,870	87,542	942,877	3,394	81	611	8,297,318	7.65	1.33
5	Installation of Power Factor Improvement (PFI) plant	15,000,000	130,435	92,881	1,000,260	3,601	86	670	21,450,600		
6	Energy Saving Opportunity by The Installation of Roof top Solar Panel (PV system) instead Purchasing Electricity	83,809,000	728,774	149,394	1,609,000	5,792	138	1,078	14,160,369	19.77	0.70
7	Replacing Inefficient Motors with Efficient (IE3 94.6% efficiency) Motors.	100,000,000	869,565	315,149	3,393,977	12,218	292	2,274	29,900,939	13.05	5.92
8	Energy Saving Opportunity by Systematically detect compressed air leaks using an ultrasonic measuring device	460,000	4,000	-	-	-	-	-	115,000	27.56	3.34
9	Energy Saving due to Cleaning of the Condenser of CO2 Compressor	20,000,000	173,913	563,529	-	21,848	524	980	7,223,607	0.11	4.00
10	Improve Existing Lighting Systems by More Energy Efficient LED Lamps	23,481,200	204,184	138,896	1,495,770	5,385	129	909	13,162,776	6.66	2.77
11	Replacement of existing Ceiling fans by more energy efficient fans	42,000,000	365,217	109,801	1,182,600	4,257	102	719	10,406,880	12.13	1.78
12	Energy Saving opportunity by introducing Jockey pump instead of Continuous running of Motor Driven Fire pump in the Fire Water System	350,000	3,043	25,742	277,400	998	24	186	2,441,120	9.59	4.04
	Total	**302,134,400**	**2,627,256**	**2,229,469**	**9,901,884**	**86,436**	**2,066**	**9,105**	**108,486,549**	**100.00**	**2.78**

Table 32: Low-Cost ECMs

SL No.	Energy Conservation Measures (ECM)	Investment Cost		Annual Savings						% share of of Identified Savings	Payback Period
		BDT	USD	NG (m^3)	Electricity in kWh	GJ	TOE	t-CO2 (MT/yr)	BDT	BDT	Years
1	Energy Saving Opportunities from Uninsulated Pipeline (calculation based on 1m2 surface area)	9,200	80	1,965	-	76	2	14	31,440	0.03	0.29
2	Energy Saving Opportunity by Systematically detect compressed air leaks using an ultrasonic measuring device	460,000	4,000	-	-	-	-	-	115,000	0.11	4.00
3	Energy Saving opportunity by introducing Jockey pump instead of Continuous running of Motor Driven Fire pump in the Fire Water System	350,000	3,043	25,742	277,400	998	24	186	2,441,120	2.25	0.14
	Total	**819,200**	**7,123**	**27,707**	**277,400**	**1,074**	**26**	**200**	**2,587,560**	**2.39**	**0.32**

MEDIUM-COST ENERGY CONSERVATION MEASURES (ECMS)

Table 33: Medium-Cost ECMs

SL No.	Energy Conservation Measures (ECM)	Investment Cost		Annual Savings						% share of of Identified Savings	Payback Period
		BDT	USD	NG (m^3)	Electricity in kWh	GJ	TOE	t-CO2 (MT/yr)	BDT	BDT	Years
1	Minimize Boiler Blowdown by Installing Automatic Blowdown Control Valves.	4,000,000	34,783	744,571	-	28,867	689	1,664	812,000	0.75	4.93
2	Boiler Blow Down Water Use as Cooling Tower Make-Up Water	2,000,000	17,391	-	-	-	-	-	484,500	0.45	4.13
	Total	**17,025,000**	**148,043**	**832,113**	**942,877**	**32,261**	**770**	**2,275**	**9,593,818**	**8.85**	**1.77**

HIGH-COST ENERGY CONSERVATION MEASURES (ECMS)

Table 34: High-Cost ECMs

SL No.	Energy Conservation Measures (ECM)	Investment Cost		Annual Savings						% share of Identified Savings	Payback Period (Years)
		BDT	USD	NG (m^3)	Electricity in kWh	GJ	TOE	t-CO2 (MT/yr)	BDT	BDT	
	Energy Saving Opportunities from Cooling & Water Intake pumps	11,025,000	95,870	87,542	942,877	3,394	81	611	8,297,318	7.65	1.33
1	Installation of Power Factor Improvement (PFI) plant	15,000,000	130,435	92,881	1,000,260	3,601	86	670	21,450,600	19.77	0.70
2	Energy Saving Opportunity by The Installation of Roof top Solar Panel (PV system) instead Purchasing Electricity	83,809,000	728,774	149,394	1,609,000	5,792	138	1,078	14,160,369	13.05	5.92
3	Energy saving measure: Analysis of replacing inefficient motors with efficient (IE3 94.6% efficiency) motors.	100,000,000	869,565	315,149	3,393,977	12,218	292	2,274	29,900,939	27.56	3.34
4	Energy Saving due to Cleaning of the Condenser of CO2 Compressor	20,000,000	173,913	563,529	-	21,848	524	980	7,223,607	6.66	2.77
5	Improve existing lighting systems by more energy efficient LED lamps.	23,481,200	204,184	138,896	1,495,770	5,385	129	909	13,162,776	12.13	1.78
6	Replacement of existing Ceiling fans by more energy efficient fans	42,000,000	365,217	109,801	1,182,600	4,257	102	719	10,406,880	9.59	4.04
	Total	**284,290,200**	**2,472,089**	**1,369,650**	**8,681,607**	**53,101**	**1,271**	**6,630**	**96,305,171**	**88.77**	**2.95**

Table 35: Financial Assessment of Energy Conservation Measures

SL No.	Energy Conservation Measures (ECMs)	Investment Cost (BDT)	Financial Savings (BDT)	Payback Period (Years)	IRR (%)	NPV(BDT)	Project Lifetime (Year)
1	Minimize Boiler Blowdown by Installing Automatic Blowdown Control Valves.	4,000,000	812,000	4.93	15.33	713,271	15
2	Boiler Blow Down Water Use as Cooling Tower Make-Up Water	2,000,000	484,500	4.13	21.93	1,136,433	15
3	Energy Saving Opportunities from Uninsulated Pipeline (calculation based on 1m2 surface area)	9,200	31,440	0.30	342.00	106,924	5
4	Energy Saving Opportunities from Cooling & Water Intake pumps	11,025,000	8,297,318	1.33	75.00	26,623,752	10
5	Installation of Power Factor Improvement (PFI) plant	15,000,000	21,450,600	0.70	143.00	92,655,597	10
6	Energy Saving Opportunity by The Installation of Roof top Solar Panel (PV system) instead Purchasing Electricity	83,809,000	14,160,369	5.92	14.00	10,124,353	15
7	Replacing Inefficient Motors with Efficient (IE3 94.6% efficiency) Motors.	50,000,000	29,900,939	3.34	30.00	123,343,377	20
8	Energy Saving Opportunity by Systematically detect compressed air leaks using an ultrasonic measuring device	460,000	115,000	4.00	25.00	-	10
9	Energy Saving due to Cleaning of the Condenser of CO2 Compressor	20,000,000	7,223,607	2.77	35.00	24,913,335	15
10	Improve Existing Lighting Systems by More Energy Efficient LED Lamps	23,481,200	13,162,776	1.78	48.22	23,967,662	5
11	Replacement of existing Ceiling fans by more energy efficient fans	42,000,000	10,406,880	4.04	24.47	35,733,603	20
12	Energy Saving opportunity by introducing Jockey pump instead of Continuous running of Motor Driven Fire pump in the Fire Water System	350,000	2,441,120	0.14	697.46	13,442,872	10
	Total	**252,134,400**	**108,486,549**	**2.78**	**-**	**352,761,179**	**12.5 (avg)**

Table 36: Comparison of Low, Medium & High Cost ECMs

SL No	Category of ECM	Investment (BDT)	Annual Savings (BDT)	Pay Back Period (Years)	% Share of Identified Savings
01	Low-Cost ECMs	819,200	2,587,560	0.32	2.39
02	Medium-Cost ECMs	17,025,000	9,593,818	1.77	8.85
03	High-Cost ECMs	284,290,200	96,305,171	2.95	88.77
	Total	**302,134,400**	**108,486,549**	**2.78**	**100.00**

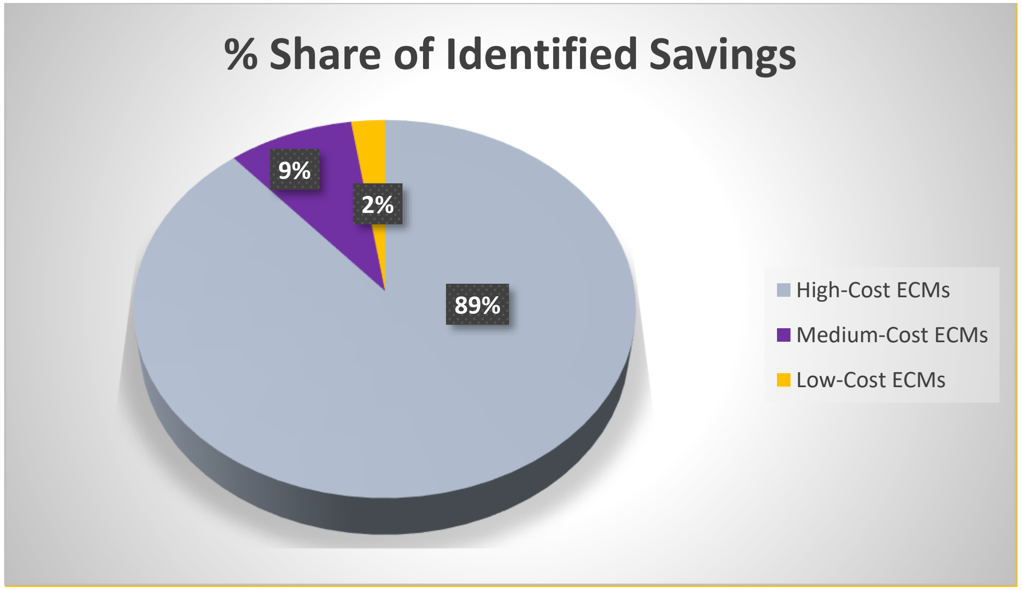


Figure 39: Comparison of Low, Medium & High Cost ECMs

CHAPTER 1: FACTORY DESCRIPTION

1.1 BACKGROUND

In the pursuit of advancing sustainable practices and enhancing energy efficiency within electricity and heat-intensive facilities, including power plants and industrial complexes, SREDA and GIZ jointly organized the "Advanced Level Hands-on Energy Audit Training on Fertilizer Industries Benchmark Development." This program took place at Ashuganj Fertilizer and Chemical Company Limited (AFCCL) in Ashuganj, B.Baria, Bangladesh, spanning from May 11 to May 16, 2024.

Established in 1981 in Ashuganj, B.Baria District, AFCCL stands as a vital entity in Bangladesh's fertilizer industry. With an annual installed capacity of 3,06,900 MT Urea and 5,28,000 MT Ammonia, the facility relies on indigenous natural gas as its primary raw material and fuel. AFCCL was instituted by the Government of Bangladesh (GOB) with the overarching objectives of meeting domestic nitrogenous fertilizer demand, bolstering crop production, and reducing reliance on foreign currency.

Having surpassed its prime production period and operated for 41 years, AFCCL faced challenges stemming from the scarcity and rising costs of natural gas. The initial design, formulated during the gas surplus of the Eighties, encountered sporadic disruptions, impeding production processes. Acknowledging the need for a transformative approach, SREDA and GIZ took the initiative to showcase the untapped potential for energy savings and establish an energy benchmark in Bangladesh's fertilizer industry. This led to the implementation of an energy audit at AFCCL.

A team of certified energy auditors conducted the audit during the specified period, aiming to improve the energy efficiency (EE) of the factory through a combination of technical and organizational measures. The envisioned outcomes include not only lower energy costs but also a significant reduction in CO2 emissions. This initiative underscores the commitment of SREDA, GIZ and AFCCL to propel the fertilizer industry towards sustainable and energy-efficient practices, aligning with broader environmental and economic goals.

This background sets the stage for the subsequent audit report, which will delve into the findings, recommendations, and potential avenues for further improvements identified during the energy audit at Ashuganj Fertilizer and Chemical Company Limited.

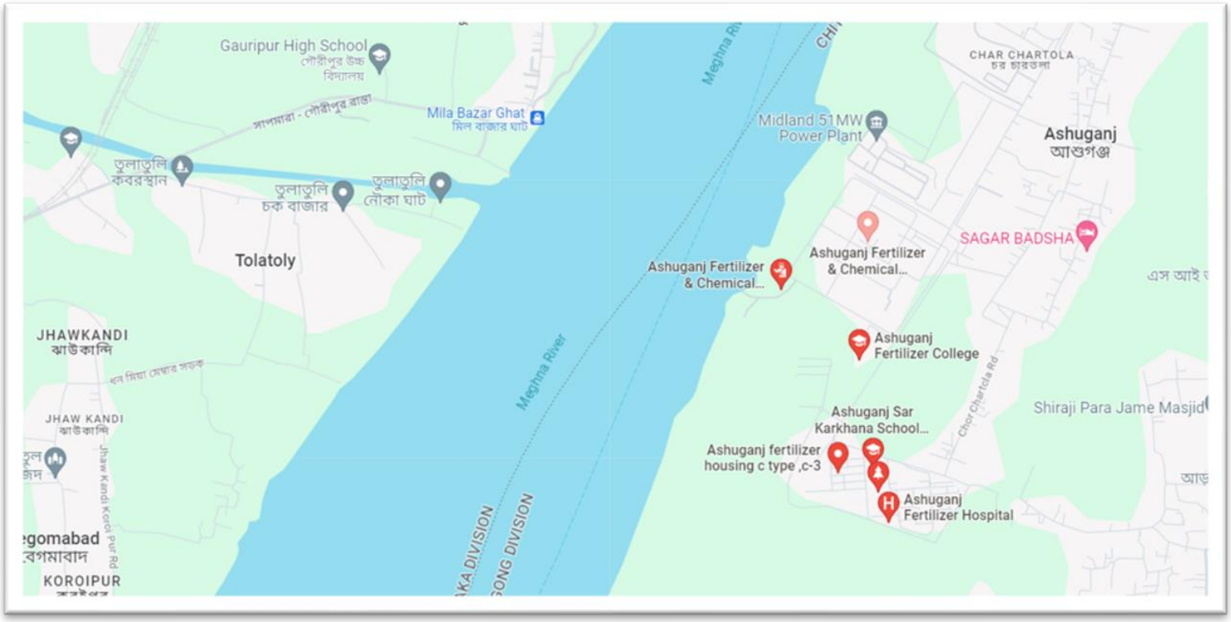


Figure 40: Location of Ashuganj Fertilizer & Chemical Company Limited

1.2 Objectives of the Energy Audit

The energy audit at Ashuganj Fertilizer and Chemical Company Limited (AFCCL) aims to systematically evaluate the energy usage and efficiency of various processes within the facility. The primary objectives of conducting the energy audit are as follows:

i. Assess and identify the current energy consumption trends across the facility to understand usage patterns in different processes and operations.
ii. Determine the efficiency of energy use within various processes, identifying areas where energy is being wasted or used inefficiently.
iii. Identify opportunities for reducing energy costs through optimized energy consumption, improved operational efficiency, and the implementation of cost-effective energy-saving measures.
iv. Explore ways to minimize carbon emissions by improving energy efficiency and adopting cleaner energy practices.
v. Recommend potential upgrades or replacements of existing equipment and technologies to enhance energy efficiency and reduce operational energy consumption.
vi. Promote a culture of energy conservation by educating employees on best practices and the importance of energy efficiency within the workplace.
vii. Identify potential risks related to energy consumption, including safety hazards, system reliability issues, and potential operational disruptions.

By achieving these objectives, the energy audit will help the factory enhance its energy performance, reduce operational costs, and contribute to its sustainability goals.

1.3 Scope of Energy Audit

The scope of an energy audit at Ashuganj Fertilizer and Chemical Factory is comprehensive and involves a detailed examination of energy consumption, production processes, and potential areas for improvement. Here are key aspects included in the scope of the energy audit: fertilizer factory:

- Overall Energy Consumption Analysis and Benchmarking: Assess the total energy consumption of the facility, including electricity, natural gas, and other energy sources. Break down energy consumption by different processes and operations within the factory.
- Process Energy Analysis: Evaluate the energy intensity of key production processes involved in urea manufacturing.
- Examine the efficiency of equipment such as compressors, pumps, boilers, and steam turbines.
- Utility Systems Evaluation: Analyze the efficiency of utility systems, including steam and electricity generation.
- Examine the energy efficiency of ammonia synthesis, which is a key precursor in urea production.
- HVAC and lighting systems assessment.
- Explore opportunities for capturing and utilizing waste heat generated during various processes. Recommend strategies for implementing waste heat recovery systems to improve overall energy efficiency.
- Evaluate the efficiency of process control systems and instrumentation.
- Identify opportunities for optimizing control strategies to enhance energy performance.
- Assess the effectiveness of existing energy management practices within the facility. Recommend improvements in energy monitoring, reporting, and management systems.
- Conduct a life cycle cost analysis for potential energy-saving measures. Estimate the rough initial investment and assess the financial feasibility with respect to long-term operational and maintenance costs.
- Explore opportunities for integrating renewable energy sources, such as solar into the facility's energy mix.
- Evaluate the environmental impact of the facility's energy consumption, with a focus on carbon emissions and other pollutants.

1.4 METHODOLOGY

Based on the scope of work, the following steps were followed during the Energy Audit:

- A field survey was conducted towards the collection of existing operational information and data pertaining to the project area.
- Secondary data was collected from factory concerns. Assigned Engineer, supervisor, operators for machines were involved in the process while collecting data.
- The technical aspects of the existing facilities were understood and noted down to be analyzed later. It was necessary to analyze any further possible energy-efficient methods or techniques to follow.
- Potential power-consuming sources were identified.
- Catalogs of different machines were collected.
- To collect periodic consumption data, bills, monthly and yearly reports were accumulated.
- On the basis of collecting relevant data, identification of potential impacts has been done using the checklists method.
- Measuring power through different sensor-based devices.

1.5 FACTORY DESCRIPTION

Ashuganj Fertilizer & Chemical Company Ltd (AFCCL) was established by the ministry of industries (MOI) of government of Bangladesh (GOB). The main contractor was Foster Wheeler Limited, UK and Commissioning was done on the 15th December 1981. Later on, at 1st December 1985, the factory way handed over to Bangladesh Chemical Industries Corporation (BCIC). The factory has a rated capacity to produce 1,600 MT of urea and however, due to gas shortage, daily production is currently close to 1200 MT. The plant is running at 70% load. The instruments were state of the art back then. But after 40 years they are functioning well enough. But still, it is one of biggest industries in Bangladesh. Watching how the machine operates was really a pleasant sight to us. We learnt many things from the fertilizer Company. The general information of the factory are as follows:

Table 37: Factory Construction Overview

General Contractor	Foster Wheeler Limited, UK
Type of Contract	Cost Plus Fees
Financial Sources	IDA, ADB, US-AID, KFW (Germany), ODM (UK), GOS (Switz), GOI (Iran), OPEC, IFAD, EEC
Capital Invest/Project Cost	TK.7577.41 million (469 million USD) @Date: 30.06.1983
Commercial Production Date	1st July,1983
Construction Period	1975 to 1981
Total Area	536.13 Acres

Table 38: Daily Requirements of Raw Materials

NG /M.Ton of Urea	30.2 MCF
NG /M.Ton of Ammonia	41.57 MCF
CO2/M.Ton of Urea	755 Kg
Ammonia/M.Ton of Urea	570 Kg

Table 39: Capacity of the Key Auxiliary Facility

Power Generation (STG)	2 X 13.5 MW
Emergency Power Generation (EDG)	0.15 MW
Ammonia Storage Capacity	10,000 MT
Bulk Urea Storage Capacity	40,000 MT
Bagged Urea Storage Capacity	22,000 MT

1.6 Production Process

The major processes of the Ashuganj Fertilizer and Chemical Factory can be classified into three major sections like production of ammonia, production of urea and the utility section. The design/process licensor of ammonia and urea production process is F. UHDE GmbH, Germany and STAMICARBON B.V., The Netherlands respectively.

1.6.1 Ammonia Production Process

The primary raw material for urea production is ammonia. Ammonia is synthesized through the Haber-Bosch process, which involves the reaction of nitrogen and hydrogen under high pressure and temperature in the presence of a catalyst. The production process of ammonia is as follows:

i. NG is available at 45 bar pressure. It passes through the knockout drum to remove any objectionable impurities. The NG is then preheated with LP steam to avoid hydrate formation and then splitted into two streams i.e., fuel gas and process gas.
ii. The pre-heated process NG is mixed with hydrogenation gas from synthesis Gas Compressor and then further heated in the flue gas duct of primary reformer.
iii. The mixed gas passes through desulfurization reactor consisting of Cobalt Molibodate catalyst bed and Zinc oxide catalyst beds where sulfur compounds are removed.
iv. The desulfurized NG is mixed with process steam and feed to the primary reformer in presence of Ni-catalyst at a pressure of 28.5 Kg / cm2 & a temperature of 400° C. The reactions are endothermic. The required thermal energy is supplied by a mixture of fuel gas, purified gas from co2 absorber and purge/ flash gases. The primary reformer is box type and top firing with preheated forced draft air. The hot flue gases leaving the primary reformer is led to the flue gas duct where

the heat is recovered by heat exchanger. The cooled flue gases are rated to the stack via I.D. fan.

v. The hot process gas (hydrogen & CO) from the primary reformer is sent to Secondary Reformer where the preheated process air compressed by process air compressor is admitted.

vi. Equilibrium conditions between the reaction products are established in presence of Ni-catalyst. As a result, CH_4 content is reduced.

vii. The hot reformed gas from the Secondary Reformer passes through process gas cooler & boiler feed water pre-heater and then fed to high temperature shift converter.

viii. The reformed gas is subjected to CO shift reactor in two adiabatic stages i.e. high temperature Shift converter (HTSC) & low temperature Shift converter (LTSC). The reaction is exothermic. The hot process gas leaving HTSC which contains the catalyst of ferrous oxide and Chromium oxide is cooled in Methanator Trim Heater and Boiler feed water pre-heater. The cooled process gas passes through LTSC where the remaining CO and water is further converted to CO_2 & H_2 by the catalyst based on Cu, Zn & Al at low temperature.

ix. The process gas flows through two stage CO_2 absorber bottom to top and is scrubbed by hot potassium carbonate solution (BENFIELD Solution). BENFIELD Solution contains Potassium Carbonate, Di-ethanol Amine (DEA) and Vanadium Penta oxide (V_2O_5).

x. The purified gas leaving the top of the absorber is spitted into two streams after knocking out drum. Most of the purified gas is further processed in Methanation section and a part of purified gas is routed to the fuel gas heater.

xi. The rich hot potassium carbonate solution (BENFIELD Solution) leaving the bottom of the absorber is fed to the regenerator via expansion turbine.

xii. The removed CO_2 & water vapor leaving the top of the regenerator is cooled. The cooled CO_2 after the condensate is separated, is fed to urea plant.

xiii. The purified gas from CO_2 absorber is preheated by feed/ effluent heat exchanger and its temp. is adjusted by Methanator Trim Heater before it enters Methanator. In the methanator, the residual CO &CO_2 are hydrogenated in presence of Ni-catalyst. The reaction is exothermic. The hot methanated gas is cooled.

xiv. The cooled process gas mixture contains H_2&N_2 at a ratio of 3:1 and with traces of CO_2 &CO is sent to the synthesis gas compressor after the condensate is separated. Formation of NH_3 in the reaction system takes place at a pressure of 200 atm and a temp. of (400-500) °C. The reaction is exothermic.

xv. The converted gas leaving the bottom of the converter at steam. of 370°C is fed into waste heat boiler generating medium pressure steam (42 kg/cm2G) and gas is cooled.

xvi. In ammonia chiller, the final cooling of product gases is done by evaporating liquid ammonia.

xvii. Before entering separator, the gas/ammonia mixture from the chiller is mixed with compressed make up synthesis gas. The condensed ammonia is collected in the separator and flashed into flash drum which is operated at low pressure.

xviii. The liquid ammonia from separator is preheated by heat exchanger and sent to Urea Plant.

1.6.2 Urea Production Process

Ammonia is combined with carbon dioxide in a stripper tower to form ammonium carbamate. This reaction is reversible, and the equilibrium is shifted towards urea formation by continuously inserting carbon dioxide.

I. Compressed CO_2 of 147 bar and 110-degree Celsius & Pressurized NH_3 of 155 bar and (50-60) degree Celsius. are fed into synthesis section at a molar ratio NH_3: CO_2 = 2 : 8 where due to exothermic reaction Ammonium Carbamate will be formed at a temp. of 170-180°C.

II. Ammonium carbamate is dehydrated to form urea and water by losing 3-4 Kcal/mol heat. Retention time is one hour in the reactor. After that, urea solution is sent to the stripper for purification. Here, 34% urea solution concentration is obtained which is introduced to the stripper and maintain 170–180 degree Celsius and 137-142 bar pressure, hence we obtained 58% urea concentrated solution which is passed into rectifying.

III. The gaseous component coming from urea synthesis reactors is passed to the high-pressure scrubber to cool down it and subsequently make it liquid.

IV. In the rectification section shell and tube heat exchangers are used to increase the concentration of urea solution. This happens due to evaporation of vapor and unwanted gases removed in this section.

V. Urea solution is flashed off by using pressure drop mechanism. Flash tank is connected to the ejectors which removes unwanted gas components. The urea solution is passed to the urea solution tank. 72% concentrated urea is obtained from the flash tank section.

VI. Two types of evaporators are used to make highly concentrated urea. Evaporator-1 gives 95% concentrated urea and Evaporator-2 gives 99.7% concentrated urea solution which is then transferred to the prilling tower.

VII. Prilling tower is used to form prilled urea. Here urea solution is sprayed from upper part of the prilling tower and air is passed from the bottom part of the tower.4 fans are used to cool down the air and when the urea solution comes in contact with the air, prilled urea is formed and collected in the prilling tower. From there prilled urea is sent to the bagging section.

VIII. Bagging section is divided into 3 sections: a) prilled urea distribution line b) prilled urea discharging line c) Bagged urea distribution line.

Chapter 2: Performance Assessment

The Ashuganj Fertilizer and Chemical Company Limited (AFCCL) is an energy-intensive facility, and optimizing the performance of its equipment is crucial for improving the efficiency, reliability, and overall effectiveness of its production processes. Key areas that impact energy intensity include the ammonia synthesis process and the subsequent urea synthesis steps, where enhancements in reaction kinetics and heat recovery systems can lead to significant reductions in energy consumption. The cooling and condensation stages in the urea production process are also vital, as efficient heat exchange systems can recover and reuse heat, lowering the overall energy demand. Additionally, the performance of utility systems, such as boilers and compressors, directly contributes to the energy intensity of the entire plant. Ensuring the optimal operation of these systems is essential for minimizing the facility's total energy usage.

2.1 Performance of Ammonia Plant

Table 40: Performance of the Ammonia Plant

Financial Year	Ammonia Production	Specific Energy Consumption	Specific Gas Consumption
	1000xTon	*GJ/Ton*	*mcf/Ton*
2018-19	89.165	116.65	105.31
2019-20	107.18	135.75	122.55
2020-21	85.19	171.08	154.45
2021-22	56.75	142.80	128.91
2022-23	92.036	116.17	104.88
Total	430.315	135.53	122.35

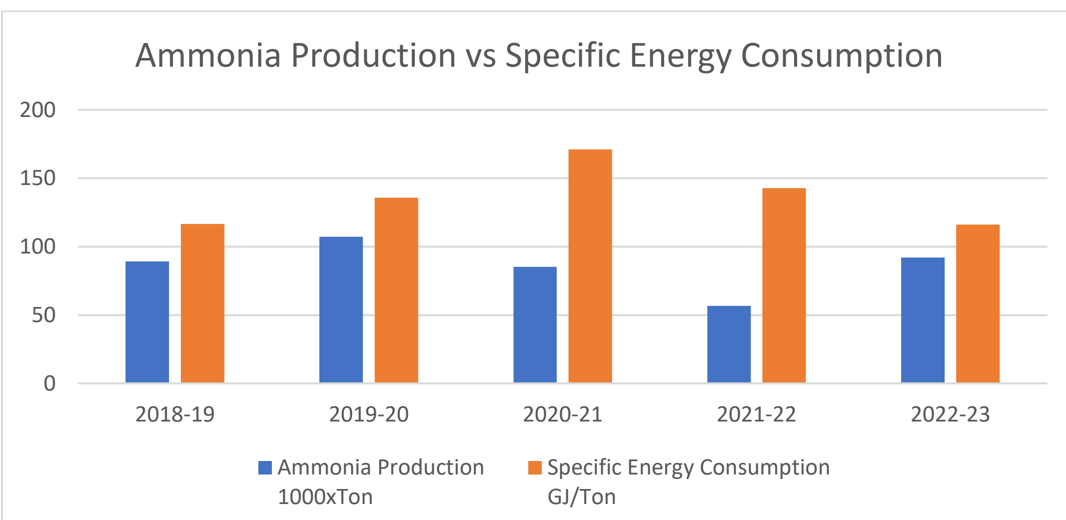


Figure 41: Ammonia Production and Specific Energy Consumption

2.2 Performance of Urea Plant

Table 41: Performance of the Urea Plant

Financial Year	Urea Production	Specific Energy Consumption	Specific Gas Consumption
	1000xTon	*GJ/Ton*	*mcf/Ton*
2018-19	150.057	69.31	62.57
2019-20	180.993	80.39	72.57
2020-21	142.557	102.23	92.29
2021-22	96.046	84.37	76.16
2022-23	157.420	67.92	61.32
Total	727.073	80.21	72.41

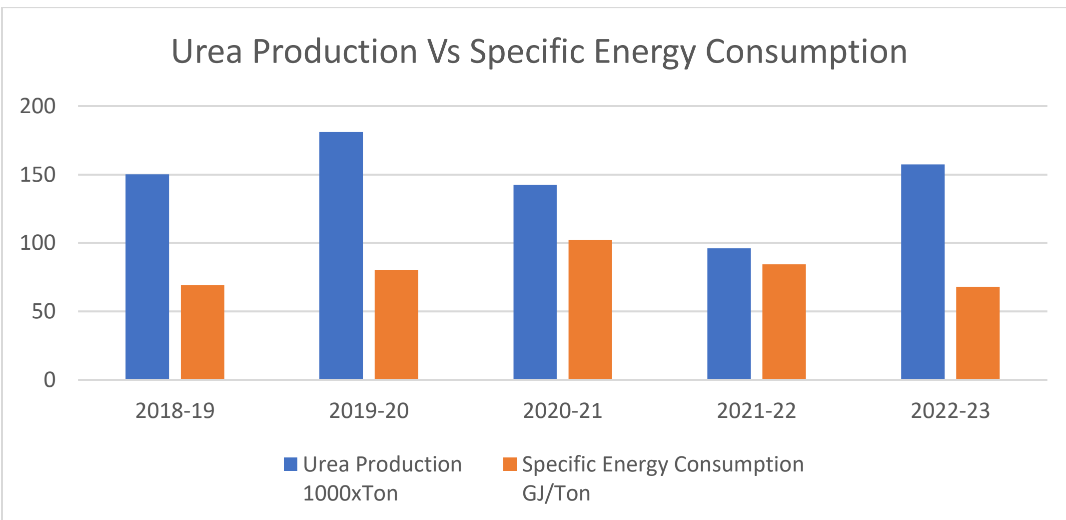


Figure 42: Urea Production and Specific Energy Consumption

2.3 PERFORMANCE OF UTILITY SECTION

2.3.1 UTILITY STEAM TURBINE:

Table 42: Efficiency of Steam Turbines

S/N	Items	Unit	ST-1	ST-2
1	Steam Inlet Flow	kg/s	11.53	**5.63**
2	Steam Pressure	bar	41	**42**
3	Steam Temperature	°C	497	**498.25**
4	Enthalpy of Steam	kJ/kg	3436.67	**3438.4**
5	Condensate Temperature	°C	38	**36.33**
6	Enthalpy of Condensate	kJ/kg	153	**152**
7	ST Back Pressure	bar	-0.76	**-0.98**
8	STG Power Output	kW	8829.17	**3133.33**
9	Power Factor	PF	0.81	**0.91**
10	STG Design Power	kW	13500	**13500**
11	Turbine Loading	%	65.4	**23.2**
12	**ST Efficiency**	**%**	**23.32**	**16.95**

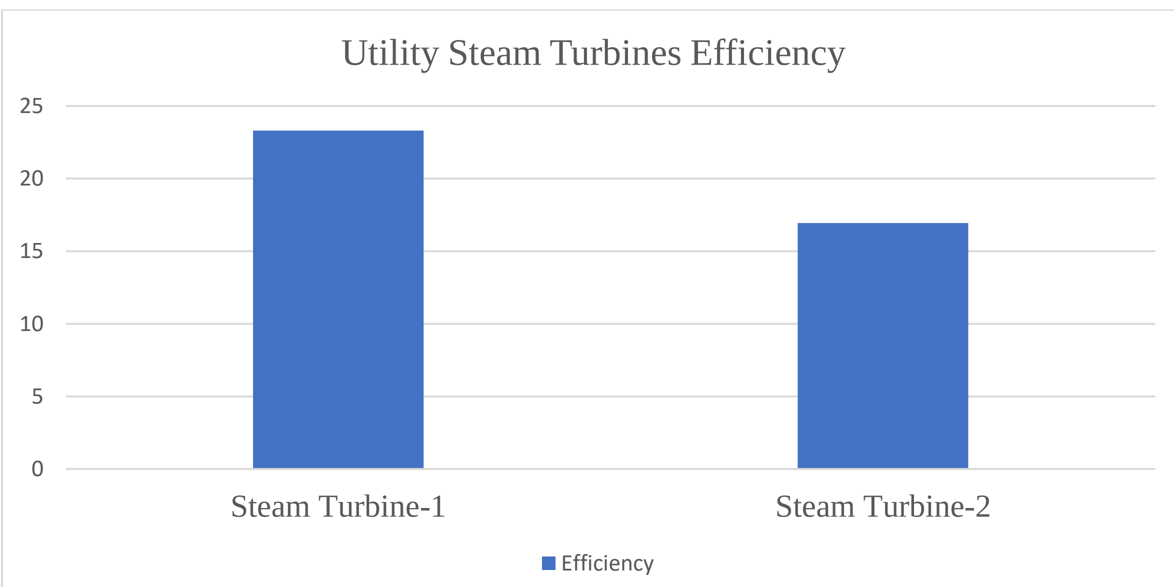


Figure 43: Steam Turbines Efficiency Comparison

CHAPTER 3: ENERGY CONSERVATION MEASURES

Reducing energy intensity at Ashuganj Fertilizer and Chemical Company Limited (AFCCL) presents a significant opportunity for both cost savings and environmental sustainability. By minimizing energy consumption, the company can lower operational expenses while simultaneously contributing to its sustainability objectives by reducing its carbon footprint and overall environmental impact. Achieving these goals requires the implementation of continuous improvement strategies, the adoption of technological advancements, and the integration of best practices in energy management throughout the fertilizer manufacturing process. Regular energy audits and consistent monitoring are critical in identifying areas for improvement and uncovering untapped potential for energy savings. These audits provide valuable insights into the facility's energy use patterns and serve as a foundation for implementing targeted measures that enhance energy efficiency. By systematically addressing inefficiencies and adopting energy-efficient technologies, AFCCL can not only optimize its energy use but also strengthen its commitment to sustainable practices, ensuring long-term benefits both economically and environmentally.

List of Energy Conservation Measures (ECM):

1. Minimize Boiler Blowdown by Installing Automatic Blowdown Control Valves
2. Boiler Blow Down Water Use as Cooling Tower Make-Up Water
3. Energy Saving Opportunities from Uninsulated Pipeline
4. Energy Saving Opportunities from Cooling & Water Intake pumps
5. Installation of Power Factor Improvement (PFI) Plant
6. Energy Saving Opportunity by The Installation of Roof top Solar Panel (PV system)
7. Replacing Inefficient Motors with Energy Efficient (IE3) Motors
8. Energy Saving Opportunity by Systematically Detect Compressed Air Leaks Using an Ultrasonic Measuring Device
9. Cleaning of the Condenser of CO2 Compressor
10. Improving Existing Lighting Systems by more Energy Efficient LED Lamps
11. Replacement of Existing Ceiling Fans by More Energy Efficient Fans
12. Introducing Jockey Pump Instead of Continuous running of Motor Driven Fire pump in the Fire Water System

ECM-1: Minimize Boiler Blowdown by Installing Automatic Blowdown Control Valves.

CURRENT PROBLEM

Boiler blowdown process has been carried out manually, and sometimes it remains in a fixed position despite the variable load conditions of the system. This lack of dynamic adjustment occurs due to either the extra effort required to manually regulate the blowdown or due to negligence in consistently monitoring and adjusting the process. As a result, the blowdown valve is left open for extended periods, causing a continuous and unnecessary discharge of hot water from the boiler. This not only leads to a significant loss of heat but also wastes energy, as the system continues to expel high temperature demi water. The failure to adjust the blowdown process in real-time according to the boiler's operational load results in inefficiencies, increased fuel consumption, and higher operating costs.

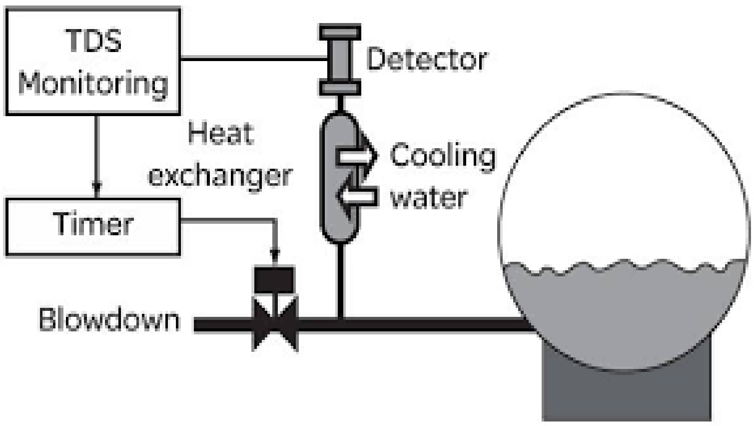


Figure 44 Automatic Blowdown Control Valve

IMPROVEMENT MEASURE

An automatic blowdown system based on Total Dissolved Solids (TDS) offers a highly efficient solution for managing boiler water quality and minimizing energy losses. The system continuously monitors the TDS levels in the boiler water to assess the concentration of dissolved solids, which can affect boiler efficiency and cause scaling or corrosion if not properly controlled. When TDS levels exceed a pre-set threshold, the system automatically activates the blowdown valve to release a measured amount of water, reducing the concentration of impurities and maintaining optimal water quality.

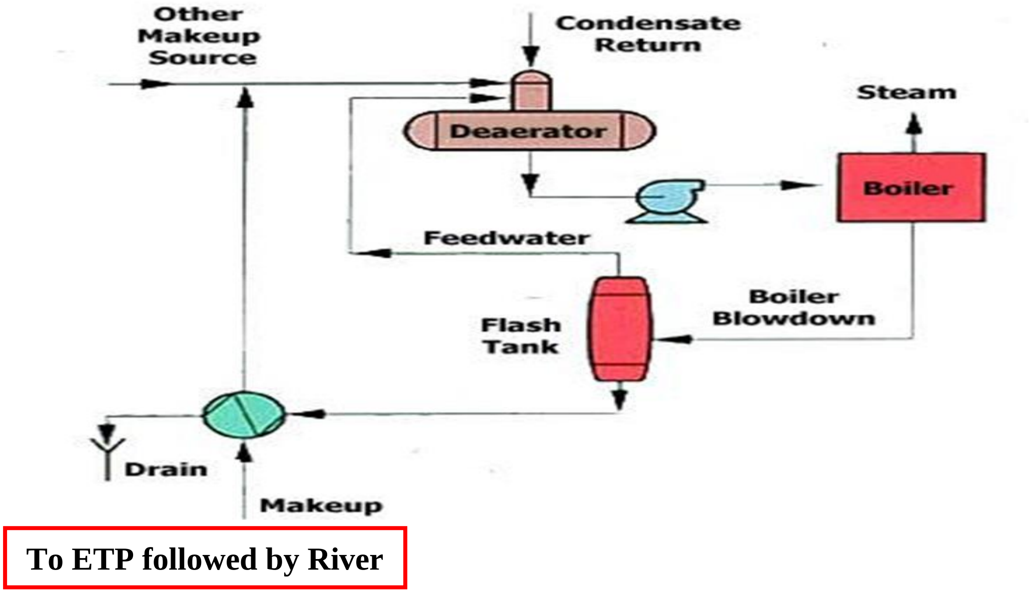
A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual Energy Savings	28,867	GJ/yr
Annual Monetary Savings for Two Boilers	8,12,000	BDT/yr
Investment	40,00,000	BDT
Project Lifetime	15.00	Years
Payback Period	4.93	Years
IRR	15.33	%
NPV	7,13,271	BDT

ECM-2: Energy Saving Scope by Boiler Blow Down Water Use as Cooling Tower Make-Up Water

CURRENT PRACTICE

Currently, high-quality boiler blowdown water is being discharged into the Effluent Treatment Plant (ETP), followed by release into the river. This practice results in the loss of potentially valuable water that could otherwise be reused within the facility.



IMPROVEMENT MEASURE

High quality boiler blowdown water can be used as cooling tower make-up because it has been observed that the parameters of the blowdown water, such as its temperature, chemical composition, and purity, comply with the required quality standards for cooling tower water.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual Savings (Cooling Tower Makeup Water)	19,380	Ton/yr
Annual monetary savings for two boilers	4,84,500	BDT/yr
Investment	20,00,000	BDT
Project lifetime	15.00	Years
Payback period	4.13	Years
IRR	21.93	%
NPV	11,36,433	BDT

ECM-3: Energy Saving Opportunities from Uninsulated Pipeline

CURRENT PRACTICE

At several locations on process and fuel gas pipelines insulation were missing and damaged. Also control valves, nonreturnable valves, flange connections, heat exchanger vessels etc. insulation found distorted and rainwater intrusion to insulation causing Corrosion Under Insulation (CUI) & thickness reduction. Each hot spot-on energy intensive surface area like high pressure superheat steam carrying vessel and pipes prone to loss significant amount of energy.

Reformer feed line with uninsulated non return valve

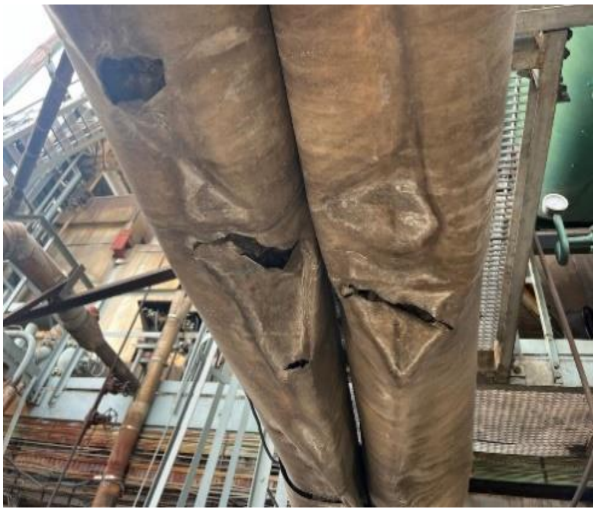
Uninsulated vessel part

Uninsulated valve

Broken cladding has the potential of water ingression

Insulation not sealed, due water ingression Corrosion Under Insulation (CUI) observed. CUI cause reduce thickness and increase heat loss.

Uninsulated bllind and pipe in ammonia section



Broken cladding and damaged insulation inside

Uninsulated pipeline

IMPROVEMENT MEASURE

High temperature, low temperature, medium temperature processes pipeline insulation has the potential to save significant amount of energy.

It is always important to identify the weak point of insulation & seal it with waterproof lamination to prevent Corrosion Under Insulation (CUI).

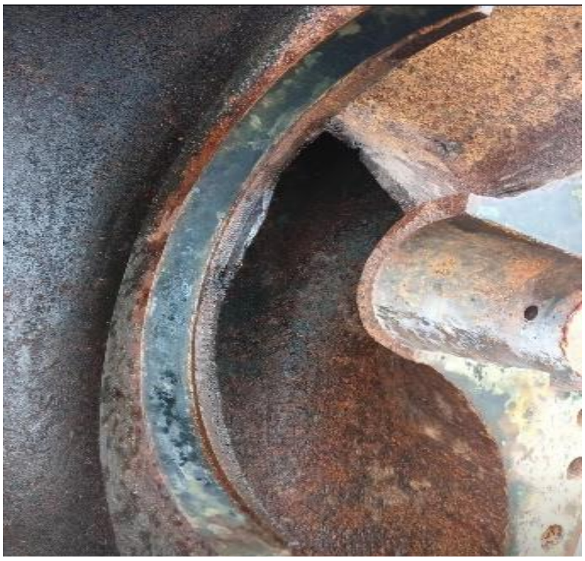
Figure 45: Insulated pressure vessel and pipe

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual Energy Savings	76	GJ/m2
Annual Monetary Savings for 1 m^2 Insulation	31,440	BDT/yr/m2
Investment	9,200	BDT/m2
Project Lifetime	5	Years
Payback Period	0.3	Years
IRR	342	%
NPV	83,645	BDT

CURRENT PRACTICE:

During the facility inspection, it was observed that several running pumps exhibit signs of leakage and significant corrosion. These pumps are relatively old and have predominantly been maintained on corrective basis only. As a result, there is a suspected decline in system performance, with low head and flow rate expected due to potential wear and degradation of key pump components.

IMPROVEMENT MEASURE

1. Dismantle the pump upper casing, and shaft (with its components) to check the problem causes.
2. Find out corrosion in upper and lower casing, exactly at wear ring replacement as shown in pic.
3. Check gap clearance between casing and impeller wear rings.
4. Restoration the pump casing with Ceramic Resurfacing Services. (Ceramic resurfaceing is the application of a ceramic coating or layer onto the surface of a pump or other equipment to enhance its appearance, durability, and performance.)
5. Replace casing wear rings with new according to STD, also DE & ND.

The recommended actions including Ceramic surface coating could improve pump efficiency 5 to 8%.

Ceramic coating (Belzona®1341 one of the recommended coatings) for double suction centrifugal pumps have demonstrated improvement of 5% efficiency minimum in industrial application.

Considering this minimum improvement, Cooling and Water intake pumps could save annually 943 MWh electrical energy.

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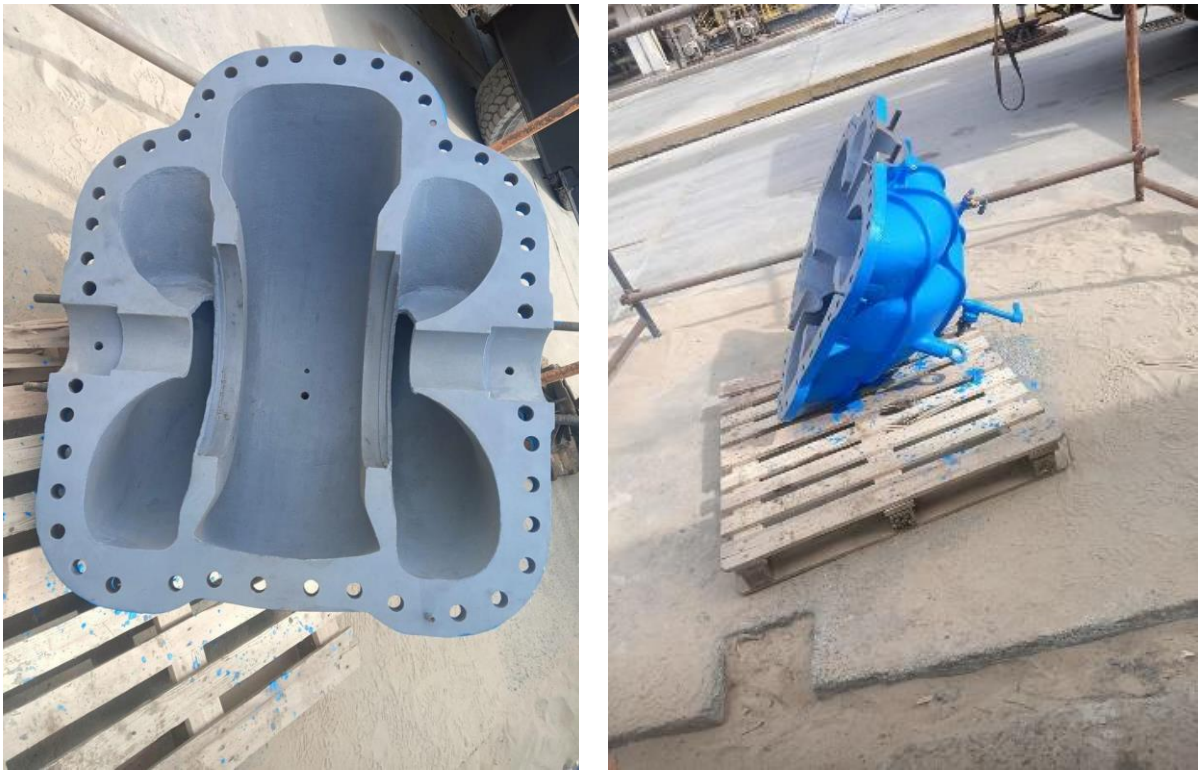


Figure 46: Condition after ceramic coating of the pump

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual Electricity Savings	943	MWh/year
Annual Monetary Savings	8,297,318	BDT/year
Investment	11,025,000	BDT
Project Lifetime	10	Years
Payback Period	1.33	Years
IRR	75	%
NPV	2,66,23,752	BDT

ECM-5: Installing Power Factor Improvement (PFI) Plant

CURRENT PRACTICE

Upon inspection, it was determined that there is no Power Factor Improvement (PFI) unit is available at plant. Consequently, the fluctuation in power factor observed over the past 12 months, ranging from 0.49 to 0.92, has resulted in significant electricity expenses totaling 8,812,290 BDT for AFCCL. To mitigate the risk of penalties imposed by BPDB and reduce the I^2R losses, it is imperative to maintain a power factor of 0.95 or higher.

IMPROVEMENT MEASURE

Installing the PFI plant offers several compelling benefits. Firstly, it will stabilize the power factor, ensuring compliance with BPDB regulations and eliminating the risk of penalties. By maintaining a consistently high-power factor, the AFCCL can avoid unnecessary expenses and optimize its electricity consumption.

Furthermore, an improved power factor leads to greater energy efficiency and reduced electricity bills. A higher power factor means that electrical systems operate more efficiently, resulting in lower overall energy consumption for the same level of output. As a result, installing the PFI plant not only reduces costs associated with penalties but also yields long-term savings by enhancing energy efficiency.

Moreover, a functional PFI plant contributes to the overall reliability and stability of the electrical system. By mitigating voltage drops and minimizing losses in the distribution network, the PFI unit helps to maintain optimal operating conditions and prolongs the lifespan of electrical equipment. This improved reliability translates to reduced downtime, enhanced productivity, and greater operational efficiency for the AFCCL.

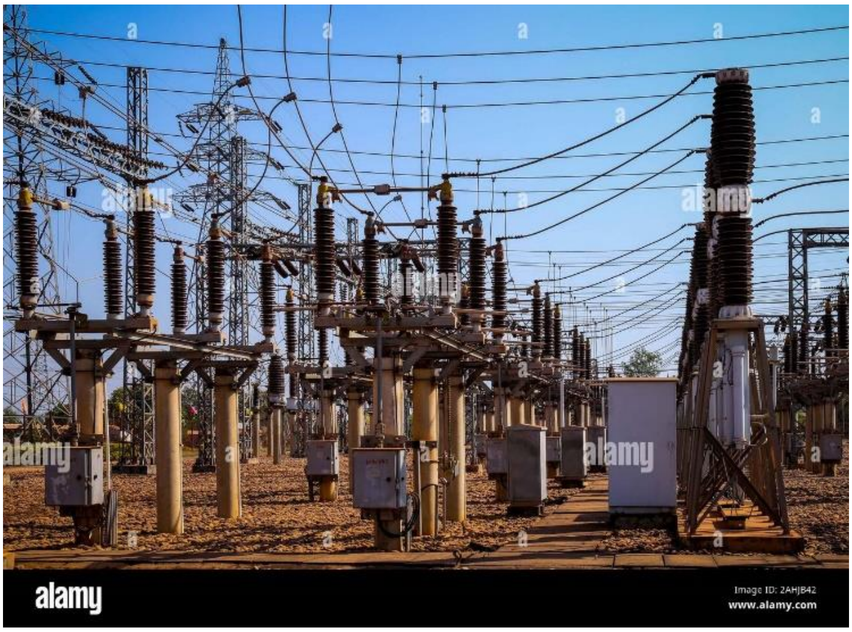
A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual Electricity Savings	1000	MWh/yr
PFI Plant Capacity (Considering monthly electrical energy consumption from Mar'23 to Feb'24)	960	kVar
Investment	15,000,000	BDT
Annual Monetary Savings (Considering both I^2R Loss & PF Penalty)	21,450,600	BDT
Project lifetime	10	Years
Payback period	0.70	Year
IRR	143	%
NPV	92,655,597	BDT

ECM-6: Energy Saving Opportunity by the Installation of Roof top Solar Panel (PV system) instead of Purchasing Electricity

CURRENT PRACTICE

Currently, the fertilizer factory operates without any solar photovoltaic (PV) systems in place, despite having substantial roof space available on its buildings with large shed areas. This lack of solar power installation means the factory is fully reliant on grid electricity, which contributes to higher operational costs and a significant carbon footprint. Additionally, the factory may be facing challenges associated with fluctuating electricity prices and dependency on non-renewable energy sources. With rising energy costs and increasing environmental concerns, the factory could be missing out on potential savings and sustainability opportunities that solar energy could offer.



IMPROVEMENT MEASURE

To improve the energy efficiency and sustainability of the factory, it is highly recommended to install solar PV panels on the available shed areas and rooftops of the buildings. This would not only help reduce the factory's reliance on grid electricity but also provide a cleaner, renewable source of energy, significantly lowering its carbon emissions. By harnessing solar power, the factory can offset a portion of its energy needs, leading to long-term cost savings through reduced electricity bills. Moreover, the factory could explore options such as government incentives, subsidies, or power purchase agreements (PPAs) to make the initial investment in solar energy more affordable. Over time, the installation of solar panels would enhance the factory's sustainability profile and contribute positively to its corporate social responsibility (CSR) goals.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual Energy Savings	1,609	MWh/yr
Annual Monetary Savings	14,160,369	BDT/yr
Solar Panel Capacity (2941 Panels of 570W)	1.68	MW
Investment	83,809,000	BDT
Project Lifetime	15	Years
Payback period	5.92	Years
IRR	14	%
NPV	10,124,353	BDT

Current Practice

Based on our inspection and data received from AFCCL, we have assessed the efficiency of existing motors at the plant, as outlined in Table 17. Our analysis revealed that the majority of motors are already efficient. There are still a few motors whose efficiency is not up to the mark (not IE3 class). We identified ten motors having capacity more than 500 kW and with efficiencies below IE-3 class efficiency which could be changed on first phase. Gradually other inefficient motors can be changed later.

Improvement Measure

In first phase, our focus is on replacing big motors like FD Fan (1000 kW), ID Fan (1200 kW), HP Solution Pumps (2×1120 kW) at the ammonia plant and three cooling water pump motors (3×1400 kW & 3×630 kW) at the utility. These motors are currently highly inefficient. We propose replacing them with IE3 motors, which boast an efficiency rating of 94.6%.

Our feasibility analysis, based on an annual operation of 4000 hours, supports the replacement recommendation. Please note that uncertainties related to natural gas availability have not been factored into this analysis.

Table 43: Analysis of efficiencies of existing motors at the plant

Description of motors	Plant	Capacity (kW)	Voltage (V)	Full Load Current (A)	Input Power (kW)	Efficiency	Recommendations
FD Fan	Ammonia	1000	11000	67.5	1118	89%	Replace with IE3 Motors
ID Fan	Ammonia	1200	11000	81.5	1349	89%	Replace with IE3 Motors
BFW Pump	Ammonia	1800	11000	113.5	1879	96%	Replace not required
HP Solution Pump	Ammonia	1120	11000	72	1192	94%	Replace with IE3 Motors
HP Solution Pump	Ammonia	1120	11000	72	1192	94%	Replace with IE3 Motors
LP Solution Pump	Ammonia	300	3300	65	323	93%	Replace not required
LP Solution Pump	Ammonia	300	3300	65	323	93%	Replace not required

Start Up Compressor	Ammonia	280	3300	74	368	76%	Replace not required
FD Fan SNC Boiler	Ammonia	447	3300	92	457	98%	Replace not required
Package Boiler Fan	Ammonia	425	3300	94.5	469	91%	Replace not required
BFW Pump	Ammonia	750	3300	155	770	97%	Replace not required
Hydrolyzer Feed Pump	Urea	132	3300	28	139	95%	Replace not required
Hydrolyzer Feed Pump	Urea	132	3300	28	139	95%	Replace not required
HP Ammonia Pump	Urea	375	3300	82	407	92%	Replace not required
HP Ammonia Pump	Urea	375	3300	82	407	92%	Replace not required
Cir. Cooler Pump	Urea	132	3300	29	144	92%	Replace not required
Cir. Cooler Pump	Urea	132	3300	29	144	92%	Replace not required
HP Carbamate Pump	Urea	280	3300	59	293	96%	Replace not required
HP Carbamate Pump	Urea	280	3300	59	293	96%	Replace not required
Prill Cooler ID Fan	Urea	150	3300	32	159	94%	Replace not required
Prill Cooler FD Fan	Urea	150	3300	32	159	94%	Replace not required
Cooling Water Pump	Utility	1400	11000	102.5	1697	82%	Replace with IE3 Motors
Cooling Water Pump	Utility	1400	11000	102.5	1697	82%	Replace with IE3 Motors

Cooling Water Pump	Utility	1400	11000	102.5	1697	82%	Replace with IE3 Motors
Water Intake Pump	Utility	170	3300	37	184	93%	Replace not required
Water Intake Pump	Utility	170	3300	37	184	93%	Replace not required
Water Intake Pump	Utility	170	3300	37	184	93%	Replace not required
Clear Well Pump	Utility	170	3300	37	184	93%	Replace not required
Clear Well Pump	Utility	170	3300	37	184	93%	Replace not required
WFI Pump	Utility	180	3300	41	204	88%	Replace not required
Cooling Water Pump	Utility	630	3300	140	695	91%	Replace with IE3 Motors
Cooling Water Pump	Utility	630	3300	140	695	91%	Replace with IE3 Motors
Cooling Water Pump	Utility	630	3300	140	695	91%	Replace with IE3 Motors

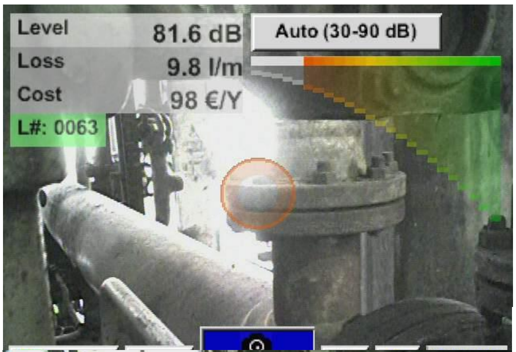
A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual Electricity Savings (Based on Motor Rating More than 500KW and Efficiency Less than IE3 efficiency)	3,393,977	kWh/yr
Annual Monetary Savings	29,900,939	BDT/yr
Investment	100,000,000	BDT
Project Lifetime	20.00	Years
Payback period	3.34	Years
IRR	30	%
NPV	123,343,377	BDT

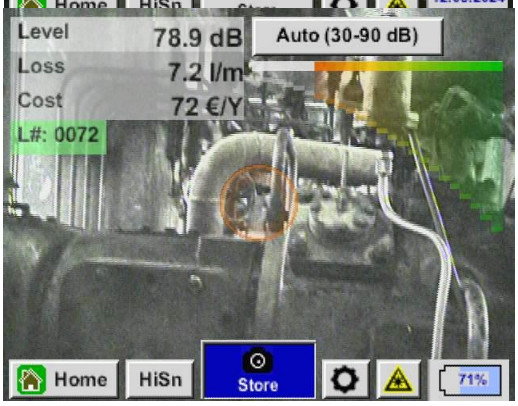
Current Problem

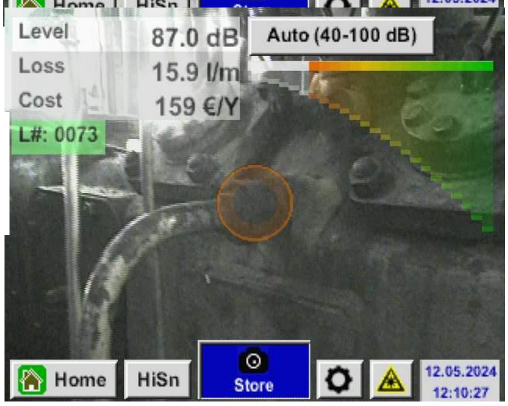
No compressed air leaks are currently recorded.

Examples of air leakage during the energy audit:



All 4 Pictures
compressor





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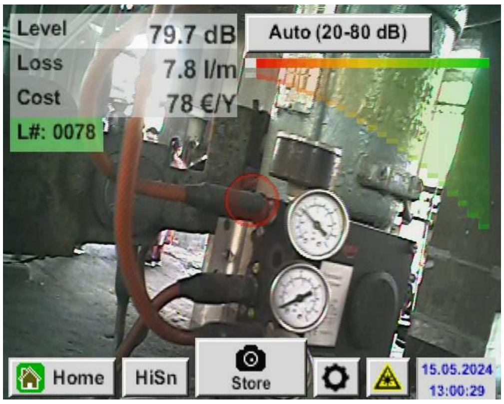
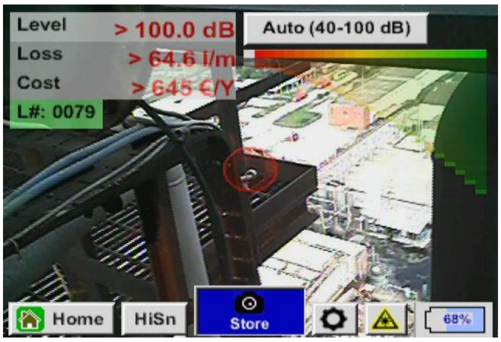


Leakage ground motor close to Prilling tower

Leakage Pressure Filter



Leakage roof of prilling tower upstairs with ladder available

Improvement Measure

Leaks can be detected and repaired immediately through regular, for example quarterly, inspections.

Figure 47: Ultrasonic Leak Detector

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Savings in the first year: With 20-40 leaks in production. Each leakage costs about 50 $ per year (estimation)	$1000.00	Dollar/yr
Cost of Compressed air leakage measuring device:	$4000.00	Dollar
Service life of the system	10.00	yrs
Payback Period (Simple)	4	yrs
NPV	N/A	BDT
IRR	25	%

ECM-9: Energy Saving due to Cleaning of the Condenser of CO_2 Compressor

CURRENT PROBLEM

Automatic condenser tube cleaning system is not incorporated in the facility. In our observation regarding the condensers and other heat exchangers, we find that due to lack of proper maintenance, condensers may be heavily fouled. After reviewing the factory provided documents, we found that Surface Condenser of CO2 Compressor (33-2104) is operating in higher shell temperature than its design value. An increase in condenser temperature often leads to an increase in condenser pressure. This is because higher temperatures in the condenser can result in a higher saturation pressure of the working fluid, which in turn increases the back pressure on the turbine, potentially reducing the efficiency of the power cycle.

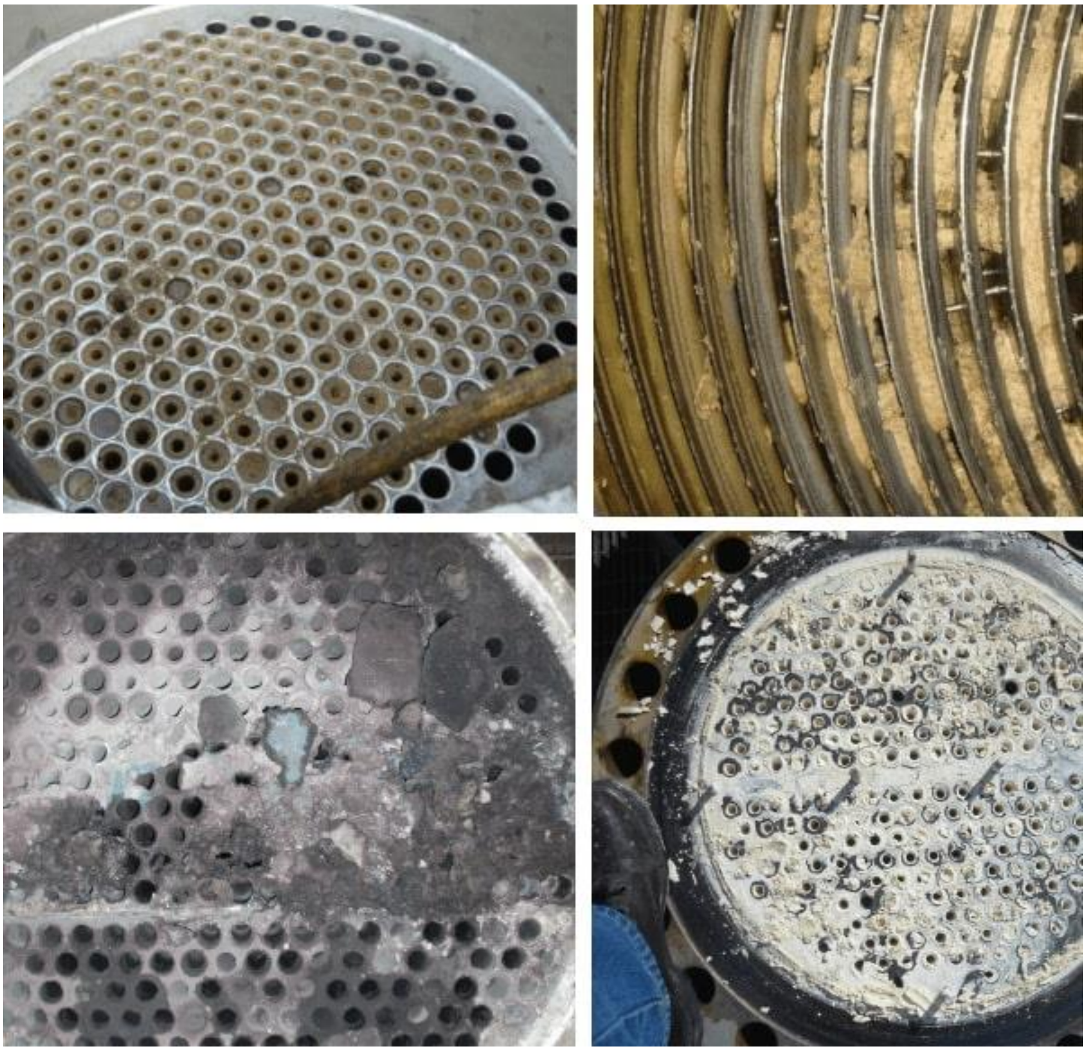


Figure 48: Uncleaned Heat Exchanger Tube

Improvement Measure

Condenser tube cleaning can lead to significant energy savings by restoring heat exchanger efficiency. Fouling, the accumulation of deposits within heat exchanger tubes, impedes thermal transfer and causes systems to work harder to achieve the desired temperature regulation, thus consuming more energy. Effective cleaning removes these deposits, allowing for better heat transfer and reducing the energy required for heating or cooling processes.

Implementing an automatic condenser tube cleaning system, such as the Taprogge system, would represent a viable and sustainable approach to effectively address this issue.

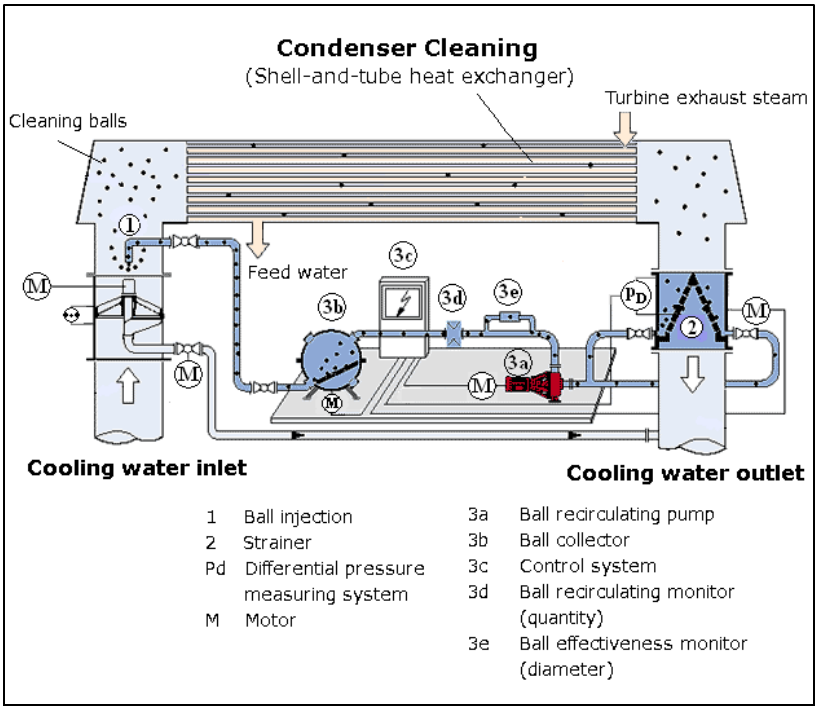


Figure 49: Automatic condenser tube cleaning system

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual Energy Savings	17,504	GJ/yr
Annual Monetary Savings	72,23,607	BDT/yr
Investment	2,00,00,000	BDT
Project Life	15	Years
Simple Payback Period	2.77	Years
NPV	24,913,335	BDT
IRR	35	%

ECM-10: Improve Existing Lighting Systems by More Energy Efficient LED Lamps.

Current Problem

The plant and facilities currently rely on a wide range of traditional lighting systems, including approximately 2500 60W incandescent light bulbs, 1500 100W incandescent bulbs, 4000 fluorescent bulbs (23W), 5000 tube lights (40W), 800 250W mercury vapor lights, and other various bulbs with lower lumen efficacy. These outdated lighting solutions consume a significant amount of energy, leading to high electricity costs and inefficiency.

Traditional lighting technologies like incandescent, fluorescent, and mercury vapor lamps typically offer lower lumen output per watt of energy consumed, resulting in suboptimal energy efficiency. Moreover, these lighting systems require frequent maintenance and replacements due to shorter lifespans, leading to additional operational costs and downtime.

Improvement Measure

Replace fluorescent bulbs by 12W LED bulbs, T-8 tubes by 20-Watt LED tube lights, Mercury light by 100 W LED light and other lights with LED lamps with required wattage. LED lights provide significantly higher luminous efficacy, meaning they produce more light per watt of electricity consumed, leading to substantial energy savings. LEDs also have longer lifespans, reducing the need for frequent replacements and minimizing maintenance costs.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual Electricity Savings	1496	MWH/yr
Annual Monetary Savings	13,162,776	BDT/yr
Investment	2,34,81,200	BDT
Project Lifetime	20	Years
Simple Payback Period	1.78	Years
IRR	48.22	%
NPV	2,39,67,662	BDT

ECM-11: Replacement of Existing Ceiling Fans by More Energy Efficient Fans

CURRENT PROBLEM

The plant and facilities are currently equipped with around 6000 traditional ceiling fans, each consuming between 80 to 100 watts of electricity. These older AC (Alternating Current) fans are less energy-efficient, resulting in high power consumption and significant electricity costs, especially considering they run for extended periods daily. Additionally, traditional fans require more frequent maintenance due to wear on brushes and mechanical components, leading to higher repair costs and potential downtime. The inefficiency of these fans not only impacts operational expenses but also contributes to unnecessary energy waste and a higher carbon footprint.

IMPROVEMENT MEASURE

To address these challenges, the proposal is to replace the existing traditional ceiling fans with energy-efficient **Brushless Direct Current (BLDC)** ceiling fans that consume only 35-40 watts. BLDC fans are significantly more energy-efficient than their AC counterparts, reducing power consumption by up to 60%, leading to substantial cost savings on electricity bills. These fans also require less maintenance due to their brushless design, resulting in lower operational costs and increased durability. Additionally, BLDC fans offer quieter operation, more precise speed control, and a longer lifespan, which can further improve the overall efficiency and sustainability of the plant's ventilation system.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual Electricity Savings	1,182	MWH/hr
Annual Monetary Saving	10,406,880	BDT/yr
Investment	4,20,00,000.00	BDT
Simple Payback Period	4.04	Years
NPV	35733603	BDT
IRR	24.47	%

ECM-12: Energy Saving Opportunity by Introducing Jockey Pump Instead of Continuous Running of Motor Driven Fire pump in the Fire Water System

CURRENT PROBLEM

The plant and the facilities have one Motor Driven Fire pump (140 KW), One Diesel Driven Fire Pump and jockey Pump in the Fire Water System. Among them jockey pump is out of order. So, motor driven fire pump always use for the fire water system and huge amount water is being wasted during this process.

IMPROVEMENT MEASURE

A jockey pump is typically used in fire protection systems to maintain system pressure and ensure that the main fire pump does not need to run unless there is a significant pressure drop, such as in the event of a fire. Using a jockey pump instead of the fire pump for maintaining system pressure can save energy because the jockey pump is usually much smaller and more energy-efficient than the fire pump. However, it's important to note that a jockey pump is not a substitute for a fire pump but a complementary component to maintain system pressure efficiently.

A snapshot of the Cost and Benefit Analysis is provided in the table below. For detailed calculations, please refer to Annexure-1.

Annual Electricity Savings	277.4	MWH/yr
Total Annual Monetary Saving	2,441,120	BDT/yr
Investment	3,50,000	BDT
Project Life	10.00	Years
Simple Payback Period	0.14	Years
NPV	1,34,42,872	BDT
IRR	697.46	%

CHAPTER 4: ADDITIONAL RECOMMENDATIONS

CHANGING THE TUBES AND CATALYST OF PRIMARY REFORMER

It has been observed that the primary reformer has had to run approximately 80% load most of the time for the last couple of years because of saving reformer tubes from overheating. Note that a large number of tubes of the same have been suffering from localized heat (hot spot) while operating above 80% load which led to bringing down plant factor resulted in lower efficiency augmenting energy consumption for generating per unit finished product consequently uplifting production cost. After deep dive analysis, the energy audit team recommended the following.

Action 1: To be replaced the catalyst located inside reformer tubes which might be deactivated/saturated/powdered owing to prolonged operation (factors like carbon deposition, sintering, or impurities in the feedstocks) resulted in creating flow resistance during higher load operation, lowering H_2 production consequently generated huge-localized heat followed by overheated tubes material.

Figure 50: Deactivated and broken catalyst.

Action 2: To be replaced the aged reformer tubes with new ones. Note that the aforementioned reformer running since inception without carrying out major overhauling.

Since catalyst/tube replacement is a big task and a large amount of cost is involved with these activities result in it is very hard to make proper estimation by the audit team, therefore, a detailed deep dive feasibility study is to be conducted in this regard.

Operation and maintenance Recommendations:

This section outlines the operation and maintenance practices can be adopted by the factory for improving efficiency and quality. We have not taken them into the analysis as we consider them to be routine activities.

Acid Cleaning of Boiler Tubes:

The exhaust flue gas from the boiler of utility section is high as 200 deg C. Acid cleaning of boiler tubes is a process used to remove scale, deposits, and corrosion from the inner surfaces of the tubes. This cleaning method is typically employed when the boiler's efficiency is affected by the accumulation of deposits, leading to higher exhaust flue gas temperatures. After cleaning, inspect the boiler tubes to ensure that deposits have been effectively removed, and the tubes are in good condition. If necessary, additional maintenance or repairs may be carried out. Monitor the boiler's performance, including exhaust flue gas temperatures, to ensure that the cleaning has had the desired effect on efficiency.

Energy efficient motors

Existing motors are conventional and consume excess energy. Consultants suggest replacing those motors with latest energy efficient motors gradually. The big motors should be given the priority.

Cooling tower maintenance

It has been observed that cleaning and maintenance of cooling towers is less frequent than required. There are some Leakage at cooling water pipelines. Regular maintenance will obviously improve the performance of the towers and will reduce the lot on compressors.

Instrumentation

Instrumentation in the boilers and other equipment is inadequate. A few vital instruments in these areas will certainly improve scope for better monitoring and control of process parameters.

Energy Assessment

It is recommended by the consultants to perform energy assessment in the factory every two or three years. This practice will enable the factory management to identify new energy savings options and will help to measure achieved savings for previous energy efficient investments. In addition, regular energy assessment will provide an energy benchmark of factory’s own perspective which will assist to analyze the production performance of the factory.

Preventive Maintenance

Preventive maintenance is maintenance that is regularly performed on a piece of equipment to lessen the likelihood of it failing. Preventive maintenance is performed while the equipment is still working, so that it does not break down unexpectedly. It is advised by the consultants to practice preventive maintenance and plan it accordingly so that any required resources are available beforehand.

Conduct Detail Study to Replace the Existing Power Generation

Replacing the existing power generation system of a fertilizer factory is a significant undertaking that requires a detailed and comprehensive study. The efficiency of the existing power generation system is much inefficient compared to modern combined cycle gas turbine power plant or gas engine generator. The co-generation efficiency may reach as high as 80%. We have studied two option to replace the power generation system. As the fertilizer industry is very old and already expired the economic life, it is difficult to suggest any modification which required large investment.

Option 1: Replace the Steam turbine and generator set with modern gas engine generator. Additionally, install an exhaust gas boiler (EGB) to generate steam.

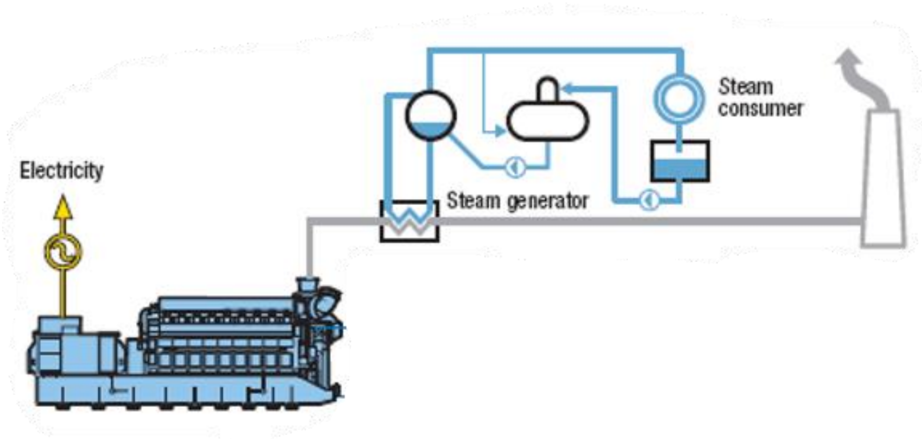


Figure 51: Gas Engine co-generation system

Option 2: Replace the whole steam and power generation system with two small size gas turbines and a heat recovery steam generator.

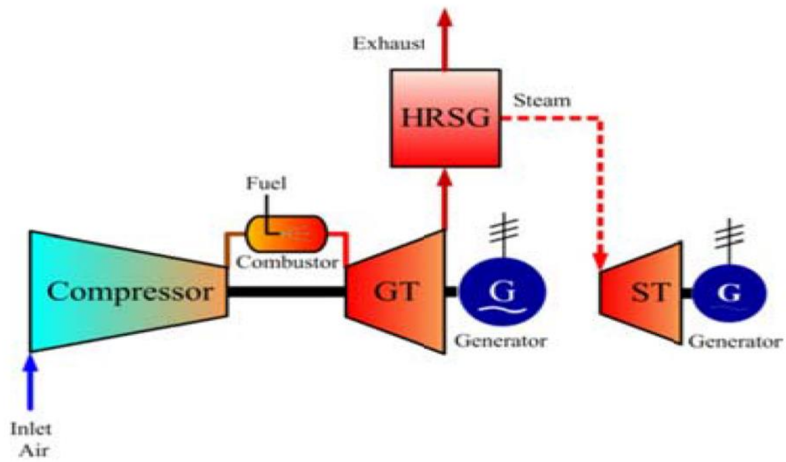


Figure 52: Gas Turbine co-generation system

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CHAPTER 5: CONCLUSION

The energy audit conducted at Ashuganj Fertilizer and Chemical Company Limited (AFCCL) has provided valuable insights into the company's current energy consumption and identified several areas where improvements in efficiency can yield significant cost savings. The audit aimed to assess the performance of existing energy systems, highlight inefficiencies, and recommend practical solutions for optimizing energy use.

Key findings from the audit revealed that various systems, including steam generation, compressed air, lighting, and cooling, were consuming more energy than necessary. Outdated equipment, poor system integration, and suboptimal operational practices contributed to these inefficiencies, leading to higher energy costs and increased wear on machinery. Addressing these issues will not only reduce energy consumption but also lower maintenance costs and extend the lifespan of critical equipment.

A key outcome of the audit was the identification of several energy-saving opportunities. Implementing these measures will improve overall operational efficiency, reduce energy costs, and enhance sustainability efforts. The audit also emphasized the importance of adopting modern energy management practices. By using more advanced technologies, such as energy-efficient motors and renewable energy sources, AFCCL can reduce its carbon footprint and align with global sustainability goals. Furthermore, real-time monitoring of energy consumption and continuous system optimization will ensure that energy savings are maintained over time.

In addition to technological upgrades, the audit stressed the need for a systematic approach to energy management. Regular maintenance, employee awareness, and continuous monitoring are essential for ensuring that energy-saving measures remain effective in the long term. A comprehensive energy management system that tracks and analyzes energy performance will help AFCCL make data-driven decisions to optimize energy use.

In conclusion, the energy audit has provided AFCCL with a clear roadmap for improving energy efficiency across its operations. By implementing the recommended measures, AFCCL can achieve substantial reductions in energy consumption, lower operational costs, and improve its environmental performance. The audit’s recommendations will also help the company remain competitive in an industry where energy efficiency and sustainability are increasingly critical. With a commitment to continuous improvement and effective implementation, AFCCL is well-positioned to benefit from both financial savings and enhanced sustainability.

ANNEXTURE: 1

STEAM TURBINE-1 FIELD DATA

Hour	P.F	MW	Steam Cons.(Ton/MW)	Steam Inlet Pressure (bar)	Vacuum Pressure (bar)	Steam Flow Rate (T/h)	Steam Inlet Temp	Condensate Temp
7:00	0.81	8.80	4.77	41	-0.76	41.4	497	38
8:00	0.81	8.80	4.77	41	-0.76	41.4	497	38
9:00	0.81	8.80	4.77	41	-0.76	41.4	497	38
10:00	0.81	8.90	4.79	41	-0.76	41.4	497	38
11:00	0.81	9.00	4.80	41	-0.76	42.0	497	38
12:00	0.81	9.00	4.80	41	-0.76	42.0	497	38
13:00	0.81	9.10	4.75	41	-0.76	42.0	497	38
14:00	0.81	9.10	4.75	41	-0.76	42.0	497	38
15:00	0.81	9.10	4.75	41	-0.76	42.0	497	38
16:00	0.81	9.10	4.75	41	-0.76	42.0	497	38
17:00	0.81	9.10	4.75	41	-0.76	42.0	497	38
18:00	0.81	9.10	4.62	41	-0.76	42.0	497	38
19:00	0.81	8.80	4.77	41	-0.76	42.0	497	38
20:00	0.81	8.80	4.77	41	-0.76	42.0	497	38
21:00	0.81	8.80	4.64	41	-0.76	42.0	497	38
22:00	0.81	8.50	4.80	41	-0.76	42.0	497	38
23:00	0.81	8.60	4.74	41	-0.76	41.4	497	38
0:00	0.81	8.60	4.88	41	-0.76	41.4	497	38
1:00	0.81	8.90	4.72	41	-0.76	41.4	497	38
2:00	0.81	8.70	4.83	41	-0.76	41.4	497	38
3:00	0.80	8.60	4.74	41	-0.76	40.2	497	38
4:00	0.80	8.50	4.80	41	-0.76	40.2	497	38
5:00	0.80	8.60	4.81	41	-0.76	40.2	497	38
6:00	0.80	8.60	4.81	41	-0.76	40.2	497	38
Avg	**0.81**	**8.83**	**4.77**	**41**	**-0.76**	**41.5**	**497**	**38**

STEAM TURBINE-2 FIELD DATA

Hour	P.F	MW	Steam Cons.(Ton/MW)	Steam Inlet Pressure (bar)	Vacuum Pressure (bar)	Steam Flow Rate (T/h)	Steam Inlet Temp	Condensate Temp
7:00	0.92	3.10	6.77	42	-0.98	19.20	500	35
8:00	0.92	3.10	6.77	42	-0.98	19.20	500	35
9:00	0.92	3.10	6.77	42	-0.98	19.20	500	35
10:00	0.90	3.00	7.00	42	-0.98	19.20	500	35
11:00	0.89	3.00	7.00	42	-0.98	19.20	500	35
12:00	0.89	2.90	7.24	42	-0.98	19.20	500	35
13:00	0.88	2.90	7.24	42	-0.98	19.20	497	36
14:00	0.88	2.90	7.24	42	-0.98	19.20	497	36
15:00	0.88	2.90	7.24	42	-0.98	19.80	500	36
16:00	0.88	2.90	7.24	42	-0.98	19.80	500	36
17:00	0.88	2.90	7.24	42	-0.98	20.40	500	37
18:00	0.88	2.90	7.24	42	-0.98	20.40	500	37
19:00	0.92	3.30	6.36	42	-0.98	21.00	501	37
20:00	0.92	3.30	6.36	42	-0.98	21.00	501	37
21:00	0.92	3.30	6.36	42	-0.98	21.00	501	37
22:00	0.92	3.50	6.51	42	-0.98	21.00	501	37
23:00	0.94	3.40	6.53	42	-0.98	21.00	497	37
0:00	0.94	3.30	6.55	42	-0.98	21.00	497	37
1:00	0.93	3.10	6.97	42	-0.98	21.00	495	37
2:00	0.93	3.20	6.94	42	-0.98	21.00	495	37
3:00	0.93	3.20	6.94	42	-0.98	21.00	494	37
4:00	0.94	3.40	6.71	42	-0.98	21.00	494	37
5:00	0.94	3.30	6.73	42	-0.98	21.00	494	37
6:00	0.94	3.30	6.73	42	-0.98	21.00	494	37
Avg	**0.91**	**3.13**	**6.86**	**42**	**-0.98**	**20.25**	**498.25**	**36.33**

CALCULATION OF ECMs

ECM-1: Minimize Boiler Blowdown by Installing Automatic Blowdown Control Valves

Operation Time	**h/yr**	**4,000.00**	**Remarks**
Cost of Cooling Tower Make-up Water (Filter Water)	BDT/L	0.025	Factory Provided data
Amount of blowdown from SNC boiler	kg/h	1,200.00	Considering 1% blowdown
Amount of blowdown from Babcock boiler	kg/h	2,030.00	Design value which is 1%
TOTAL BLOWDOWN AMOUNT	kg/h	4,845.00	
DAILY BLOWDOWN AMOUNT	kg/day	116,280.00	
YEARLY BLOWDOWN AMOUNT	kg/yr	19,380,000.00	
Annual Cooling Tower Make-up Saving	kg/yr	19,380,000.00	
Annual Monetary Saving	BDT/yr	484,500.00	
Annual Cooling Tower Make-up Saving		19,380,000.00	kg/yr
Annual monetary savings		484,500.00	BDT/yr
Investment		2,000,000.00	BDT
Project lifetime		15.00	Years
Simple Payback period		4.13	Year
IRR		21.93	%
NPV		1,136,433.66	BDT

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
	2,000,000.00			(2,000,000.00)
1.00			484,500.00	484,500.00
2.00			484,500.00	484,500.00
3.00		100,000.00	484,500.00	384,500.00
4.00			484,500.00	484,500.00
5.00			484,500.00	484,500.00
6.00			484,500.00	484,500.00
7.00		100,000.00	484,500.00	384,500.00
8.00			484,500.00	484,500.00
9.00			484,500.00	484,500.00
10.00			484,500.00	484,500.00
11.00		100,000.00	484,500.00	384,500.00
12.00			484,500.00	484,500.00
13.00			484,500.00	484,500.00
14.00			484,500.00	484,500.00
15.00		100,000.00	484,500.00	384,500.00
			NPV	$1,136,433.66
			IRR	22%

ECM-2: Boiler Blow Down Water Use as Cooling Tower Make-Up Water

Operation Time	**h/yr**	**4,000.00**	
DM WATER MAKING COST	**BDT/L**	**0.10**	**Factory Provided data**
Amount of blowdown from SNC boiler (Design)	kg/h	1,200.00	Considering 1% blowdown
Amount of blowdown from SNC boiler (Actual)	kg/h	1,791.67	
Amount of blowdown from Babcock boiler (Design)	kg/h	2,030.00	Design value which is 1%
Amount of blowdown from Babcock boiler (Actual)	kg/h	4,416.67	
TOTAL AMOUNT OF EXTRA BLOWDOWN FROM DESIGN VALUE	kg/h	2,978.33	
DAILY BLOWDOWN AMOUNT	kg/day	71,480.00	
YEARLY BLOWDOWN AMOUNT	kg/yr	8,120,000.00	
Amount of DM water saving yearly after installing automatic blowdown	kg/yr	8,120,000.00	
Steam Drum pressure	bar,g	115.70	
Steam drum temp.	°C	327.00	
Enthalphy of Saturated steam at drum	kJ/kg	2,737.40	
Input energy required to generate 1kg of steam	kJ/kg	3,555.06	Considering 77% boiler efficiency
LHV of NG	kJ/CM	35,044.14	
Annual Savings of energy	GJ	28,867.13	
Annual Savings of energy	MWh	8,018.65	
Annual Savings of energy	TOE	689.61	1 TOE=41.86 GJ
Annual Savings of NG	SCM	823,736.22	
Annual GHG gas reduction	tCO2e	1,663.95	NG emission factor 2.02 kgCO2/SCM
Annual Monetary Saving	BDT/yr	812,000.00	
Amount of DM water saving yearly after installing automatic blowdown		8,120,000.00	kg/yr
Annual monetary savings		812,000.00	BDT/yr
Investment		4,000,000.00	BDT
Project lifetime		15.00	Years
Simple Payback period		4.93	Year
IRR		15.33	%
NPV		713,271.05	BDT

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
	4,000,000.00	-		(4,000,000.00)
1.00		-	812,000.00	812,000.00
2.00		-	812,000.00	812,000.00
3.00		500,000.00	812,000.00	312,000.00
4.00		-	812,000.00	812,000.00
5.00		-	812,000.00	812,000.00
6.00		-	812,000.00	812,000.00
7.00		500,000.00	812,000.00	312,000.00
8.00		-	812,000.00	812,000.00
9.00		-	812,000.00	812,000.00
10.00		-	812,000.00	812,000.00
11.00		500,000.00	812,000.00	312,000.00
12.00		-	812,000.00	812,000.00
13.00		-	812,000.00	812,000.00
14.00		-	812,000.00	812,000.00
15.00		500,000.00	812,000.00	312,000.00
			NPV	$713,271.05
			IRR	15%

ECM-3: Energy Savings Opportunities from Uninsulated Pipelines

Discount rate	0.15
Period Year	
Initial investment	-9200
Year-1 savings	31440
Year-2 savings	31440
Year-3 savings	31440
Year-4 savings	31440
Year-5 savings	31440
IRR	342%
NPV	83,645
PB	0.29

ECM-4: Energy Savings Opportunities from Cooling & water intake pumps

NPV (Sum)	**$26,623,751.51**
Payback	**1.33**
IRR	**75%**
Initial investment	**-11025000**
Year-1 savings	8297317
Year-2 savings	8297317
Year-3 savings	8297317
Year-4 savings	8297317
Year-5 savings	8297317
Year-6 savings	8297317
Year-7 savings	8297317
Year-8 savings	8297317
Year-9 savings	8297317
Year-10 savings	8297317

ECM-5: Repair of Power Factor Improvement (PFI) plant.

Historical Data:

Month	Total Energy Consumed (kWh)	Total kVAR Consumed (kVARh)	Power Factor	Power Factor Charge	Electric Charge
Mar-23	1,263,648	1098816	0.75	161778	1,078,521
Apr-23	1,107,240	920904	0.77	1450747	10,746,275
May-23	1,379,208	1158240	0.77	1814638	13,441,765
Jun-23	1,071,864	943848	0.75	1556328	10,375,524
Jul-23	1,063,512	860112	0.78	1312809	10,296,541
Aug-23	1,019,184	792960	0.79	1184478	9,870,657
Sep-23	1,005,912	871104	0.76	1389265	9,749,230
Oct-23	982,704	931632	0.78	1432329	9,548,859
Nov-23	933,600	843600	0.74	1367192	9,114,616
Dec-23	13,200	6720	0.89	5822	129,385
Jan-24	5,520	2400	0.92	1223	54,359
Feb-24	157,008	276288	0.49	253835	1,692,233
	10002600	**8706624**		**11930444**	**86097965**

Particular	Value	Unit
PFI installation cost	15,000,000.00	BDT
Annual electrical energy consumption	10,002,600.00	kWh/a
Annual electric charge	86,097,965.00	Tk/a
Average power factor of the plant	0.75	
Recommended power factor of the plant	0.95	
Power factor correction	0.20	
Annual energy savings (Considering 10% energy saved by reducing I^2R losses)	1,000,260.00	kWh/a
Annual CO_2 Savings	670	t CO_2/a
Annual money savings by energy savings (Considering 10% energy saved by reducing I^2R losses)	8,812,290.60	BDT/a
Annual PFC charge savings	12,638,309.20	BDT/a
Total money savings	21,450,599.80	BDT/a
Payback Period	0.70	Years
Project Life	10.00	Years
Internal Rate of Return (IRR) %	143%	
NPV	92,655,597.28	BDT

ECM-6: *Energy Saving Opportunity by The Installation of Roof top Solar Panel (PV system) instead Purchasing Electricity*

Energy audit report

Presentation and calculation of potential savings

Measure Nr. 6 Installation of a PV system	**Implementation prio 2**
Actual state At present, all electricity is purchased externally. Gas is converted into electricity. This also emits CO 2.	**Target state** With your own PV system, you could use the energy you generate yourself. This would result in less gas consumption. The company would also be more flexible in the face of price fluctuations or energy shortages. Renewable energy reduces CO-2 emissions.
Assumptions for the calculation (calculation in the attachment)	
Usable area: 3.081 m²	3.081 m²
Number of solar panels (0,9 m²): 9.802	9.802 Solar Panel
Solar Panel Power 150 W	1.470.333 W (1.470 kW)
Each Costs per complete Panel (1 kW estimated 70.000 Taka) in US $ --> 1 US $ = 116 Taka:	887.270,11 $
Capacity needed of Fertilizer without running the process (office, air compressor...) per year	1.200 kW
Energy costs of Fertilizer running the process or giving electricity to the grid per year 1470 kW * 1.400 hours * 10 Taka per kWh in US $ --> 1 US $ = 116 Taka	177.454,02 $
Return on invest:	**5,91 years**
Service life of the system: 20 years	**20 years**
Necessary investments/incurring costs	887.270,11 $
Savings in the first year (20 % deduction as a risk factor):	150.000,00 $
Amortization: 5,91 years **Return on assets:** 16,92 %	
Accuracy of the calculation: +/-20% Estimate.	
Interaction with other proposed measures: None	
Measurement/verification procedure for savings achieved: Obtain an offer	
Implementation plan: Implementation according to prioritization	
Remark: Economical and environmentally friendly measure	
Priority number of the measure: 1	

ECM-7: Analysis of replacing inefficient motors with efficient (IE3 94.6% efficiency) motors.

Table : Analysis of efficiencies of existing motors at the plant

Description of motors	Plant	Capacity (kW)	Voltage (V)	Full Load Current (A)	Input Power	Efficiency	Recommendations
FD Fan	Ammonia	1000	11000	67.5	1118	89%	Replace not required
ID Fan	Ammonia	1200	11000	81.5	1349	89%	Replace not required
BFW Pump	Ammonia	1800	11000	113.5	1879	96%	Replace not required
HP Solution Pump	Ammonia	1120	11000	72	1192	94%	Replace not required
HP Solution Pump	Ammonia	1120	11000	72	1192	94%	Replace not required
LP Solution Pump	Ammonia	300	3300	65	323	93%	Replace not required
LP Solution Pump	Ammonia	300	3300	65	323	93%	Replace not required
Start Up Compressor	Ammonia	280	3300	74	368	76%	Replace with IE3Motors
FD Fan SNC Boiler	Ammonia	447	3300	92	457	98%	Replace not required
Package Boiler Fan	Ammonia	425	3300	94.5	469	91%	Replace not required
BFW Pump	Ammonia	750	3300	155	770	97%	Replace not required
Hydrolyzer Feed Pump	Urea	132	3300	28	139	95%	Replace not required
Hydrolyzer Feed Pump	Urea	132	3300	28	139	95%	Replace not required
HP Ammonia Pump	Urea	375	3300	82	407	92%	Replace not required
HP Ammonia Pump	Urea	375	3300	82	407	92%	Replace not required
Cir. Cooler Pump	Urea	132	3300	29	144	92%	Replace not required
Cir. Cooler Pump	Urea	132	3300	29	144	92%	Replace not required
HP Carbamate Pump	Urea	280	3300	59	293	96%	Replace not required
HP Carbamate Pump	Urea	280	3300	59	293	96%	Replace not required
Prill Cooler ID Fan	Urea	150	3300	32	159	94%	Replace not required
Prill Cooler FD Fan	Urea	150	3300	32	159	94%	Replace not required
Cooling Water Pump	Utility	1400	11000	102.5	1697	82%	Replace with IE3Motors
Cooling Water Pump	Utility	1400	11000	102.5	1697	82%	Replace with IE3Motors
Cooling Water Pump	Utility	1400	11000	102.5	1697	82%	Replace with IE3Motors
Water Intake Pump	Utility	170	3300	37	184	93%	Replace not required
Water Intake Pump	Utility	170	3300	37	184	93%	Replace not required
Water Intake Pump	Utility	170	3300	37	184	93%	Replace not required
Clear Well Pump	Utility	170	3300	37	184	93%	Replace not required
Clear Well Pump	Utility	170	3300	37	184	93%	Replace not required
WFI Pump	Utility	180	3300	41	204	88%	Replace not required
Cooling Water Pump	Utility	630	3300	140	695	91%	Replace not required
Cooling Water Pump	Utility	630	3300	140	695	91%	Replace not required
Cooling Water Pump	Utility	630	3300	140	695	91%	Replace not required

Energy saving measure: Analysis of replacing inefficient motors with efficient (IE3 94.6% efficiency) motors.

Particular	Value	Unit
Cost of motors replacement by IE3 motors	50,000,000.00	BDT
Annual electrical energy consumption of existing inefficient motors	38,253,491.56	kWh/a
Annual energy savings by replacing inefficient motors by IE3 (94.6% efficiency) motors	4,791,963.02	kWh/a
Annual CO2 Savings	3211	tCO2/a
Annual money savings	42,217,194.16	BDT/a
Payback Period	1.18	Years
Project Life	20.00	Years
Internal Rate of Return (IRR) %	84%	
NPV	309,418,772.58	BDT

ECM-8: Energy Saving Opportunity by Systematically detect Compressed air leaks using an ultrasonic measuring device.

Measure Nr. 8 Systematically detect compressed air leaks using an ultrasonic measuring device.	**Implementation priority 2** Employees are also will be aware for the need to save energy.
Actual state No compressed air leaks are currently recorded.	**Target state** Leaks can be detected and repaired immediately through regular, for example quarterly, inspections.
Necessary investments/incurring costs Compressed air leakage measuring device: **Savings in the first year:** With 20-40 leaks in production. Each leakage costs about 50 $ per year (estimation) **Return on invest:** **Service life of the system:**	 4.000,00 $ 20 * 50 $ = 1.000 $ **4 years** **10 years**
Amortization: 4,00 years **Return on assets:** 25,00 %	
Accuracy of the calculation: +/-20% Estimate.	
Interaction with other proposed measures: None	
Remark: **- Economical measure without great effort**	
Priority number of the measure: 2	

ECM-9: Energy Saving due to Cleaning of the Condenser of CO2 Compressor.

Enthalpy of Steam	2605	At 58 deg C
Enthalpy of Water	242	At 58 deg C
Boiler Efficiency	60%	Assumed
LHV of NG	45000	kJ/kg
Additional NG Required	116.69	kg/Hr
Yearly Operation	4000	Hr
Density of NG	0.75	kg/m3
Price of NG	16	BDT/m3
Yearly NG Savings	622,353.91	m3
	21,004.44	GJ/Year
	501.68	TOE/Year
Yearly Cost Savings	9,957,662.55	BDT
CO2 Reduction	1283.60	t-CO2/Year
Initial Investment	20,000,000	BDT
Project Life	15	Years
Discount Factor	12%	
Simple Payback Period	2.01	Years
NPV	41,539,477	BDT
IRR	49%	

Year	Investment	Operating Cost	Savings	Net Cash Flow
0	20,000,000	-		(20,000,000)
1	-	-	9,957,663	9,957,663
2	-	-	9,957,663	9,957,663
3	-	-	9,957,663	9,957,663
4	-	1,000,000	9,957,663	8,957,663
5	-	-	9,957,663	9,957,663
6	-	-	9,957,663	9,957,663
7	-	-	9,957,663	9,957,663
8	-	1,000,000	9,957,663	8,957,663
9	-	-	9,957,663	9,957,663
10	-	-	9,957,663	9,957,663
11	-	-	9,957,663	9,957,663
12	-	1,000,000	9,957,663	8,957,663
13	-	-	9,957,663	9,957,663
14	-	-	9,957,663	9,957,663
15	-	-	9,957,663	9,957,663

ECM-10: Improve existing lighting systems by more energy efficient LED lamps.

Light Wattage and Savings

S/N	Light Categroy	Existing Light (Watt, with Ballast)	Quantity	Proposed LED Light (Watt)	Operation Hours	Annual Energy Savings with all proposed LED lamps (kWh) per Year	Cost of each light bulbs (BDT); Rate: PWD SoR-2022	Total cost (BDT)
1	Compact Fl. Light (Energy Bulb)	23	4000	**12**	12	192720	294.00	1,176,000.00
2	T-8 Fl. Tube	40	5000	**20**	12	438000	491.00	2,455,000.00
3	Mercury Light	250	800	**100**	12	525600	8,999.00	7,199,200.00
4	Compact Fl. Light	60	2500	**50**	12	109500	4,641.00	11,602,500.00
5	Compact Fl. Light	100	1500	**65**	12	229950	699.00	1,048,500.00
			13800			1,495,770		23,481,200

		Unit / Remarks
OPTION-1: Total Investment (Replacing all existing Non-Energy Efficient bulbs):	23,481,200	BDT
Annual energy savings	1,495,770	kWh/Yr
Annual monetary savings @ BDT 8.80 for STG	13,162,776.00	BDT
Project Lifetime	5	Yrs
Payback Period	1.78	Yrs
NPV	23,967,661.68	BDT
IRR	48.22	%

Capital Cost (BDT)	**23,481,200.00**	
Year	Net Annual Saving (BDT)	NPV
0	-23,481,200.00	-23,481,200.00
1	13,162,776.00	11,752,478.57
2	13,162,776.00	10,493,284.44
3	13,162,776.00	9,369,003.96
4	13,162,776.00	8,365,182.11
5	13,162,776.00	7,468,912.60
Net savings	65,813,880.00	47,448,861.68
NPV		23,967,661.68
NPV		23,967,661.68
IRR		48.22%

ECM-11: Replacement of existing Ceiling fans by more energy efficient fans.

Calculation	Unit / Remarks
6000	Pcs
85	W
{365 Days X 12 Hrs} = 4380	Hr/Yr
7000	BDT (Approx. Govt. Rate)
5	Yrs
Number of fans X cost of BLDC fan = 6000 X 7000 = 42**,000,000.00**	BDT (Approx. Govt. Rate)
Number of fans X (Difference between Wattage) X Annual running hours / 1000 6000 X (85-40) X 4380 / 1000 **=1,182,600.00**	kWh/Yr
10,406,880.00	BDT
20	Yrs
4.04	Yrs
35,733,603.47	BDT
24.47	%

Net Annual Saving (BDT)	NPV
-42,000,000.00	-42,000,000.00
10,406,880.00	9,291,857.14
10,406,880.00	8,296,301.02
10,406,880.00	7,407,411.63
10,406,880.00	6,613,760.38
10,406,880.00	5,905,143.20
10,406,880.00	5,272,449.28
10,406,880.00	4,707,544.00
10,406,880.00	4,203,164.29
10,406,880.00	3,752,825.26
10,406,880.00	3,350,736.84
10,406,880.00	2,991,729.32
10,406,880.00	2,671,186.89
10,406,880.00	2,384,988.30
10,406,880.00	2,129,453.84
10,406,880.00	1,901,298.07
10,406,880.00	1,697,587.56
10,406,880.00	1,515,703.18
10,406,880.00	1,353,306.41
10,406,880.00	1,208,309.29
10,406,880.00	1,078,847.58
208,137,600.00	77,733,603.47
	35,733,603.47
	35,733,603.47
	24.47%

ECM-12: Energy Saving opportunity by introducing Jockey pumps instead of Continuous running of Motor Driven Fire pump in the Fire Water System

Description	Calculation	Unit / Remarks
Number of Motor Driven Fire Pump	1	Pcs
Electrical load of the existing Motor Driven Fire Pump	140	kW
Number of Jockey Pump	1	Pcs
Electrical load of the existing Jockey Pump	15	kW
Operation Hours (Approx.){365 Days X 24Hrs} for Jockey pump=	8760	Hr/Yr
Operation Hours (Approx.){365 Days X 8Hrs} for motor driven pump=	2920	Hr/Yr
Cost of energy efficient Jockey Pump	350,000.00	BDT
Average life of the energy efficient Jockey Pump	10	Yrs
Investment Cost of energy efficient Jockey Pump**:**	350,000.00	BDT
Annual energy savings (Number of pumps X (Difference between Wattage) X Annual running hours =1 X (140-15) X 3650	277,400.00	kWh/Yr
Annual monetary savings @ **BDT 8.80 for STG**	**2,441,120.00**	BDT
Project Lifetime	10	Yrs
Payback Period	0.14	Yrs
NPV	13,442,872.44	BDT
IRR	697.46	%

Capital Cost (BDT)	**350,000.00**	
Year	Net Annual Saving (BDT)	NPV
0	-350,000.00	-350,000.00
1	2,441,120.00	2,179,571.43
2	2,441,120.00	1,946,045.92
3	2,441,120.00	1,737,541.00
4	2,441,120.00	1,551,375.89
5	2,441,120.00	1,385,157.05
6	2,441,120.00	1,236,747.36
7	2,441,120.00	1,104,238.72
8	2,441,120.00	985,927.43
9	2,441,120.00	880,292.34
10	2,441,120.00	785,975.31
Net Savings	24,411,200.00	13,792,872.44
NPV		13,442,872.44
NPV		13,442,872.44
IRR		697.46%

ANNEXURE 2: DIFFERENT DATA SHEET

STEAM GENERATION & CONSUMPTION BREAKDOWN:

Steam Generation & Consumption Breakdown

16.02.2024

Sl. No.	Item Name	Design Steam Production (ton/hr.)	Actual Steam Production (ton/hr.)
01	SNC Boiler	120.00 (SHH)	117
02	Babcock Boiler	196 (SHH)	167
03	Waste Heat Boiler	33.90 (SMS)	22
Steam Consumption			
Sl. No.	Item Name	Design Steam Consumption (ton/hr.)	Actual Steam Consumption (ton/hr.)
Ammonia Plant			
01	Primary Reformer	81.20 (SMH)	71.00
02	Reboiler	7.10 (SLS)	7.10
03	Syn. Gas Compressor	34.00 (SMH), 195.00 (SHH)	31.02 (SMH), 180 (SHH)
04	Ammonia Compressor	18.00 (SMH)	19.80
05	Air Compressor	29.30 (SMH)	31.20
06	BFW Turbine (83-1601/02)	18 (9+9) MP	8.10
07	BFW Turbine (52-1602)	14.00 (MP)	16.20
08	Deaerator	13.50 (SLH)	4.00
09	Air Coil	4.00 (MP)	-
10	NG Preheater	3.00 (SLH)	2.0
11	Ejector	2.10 (SLS)	2.0
12	Process Air Compressor L.O Turbine	8.00 (MP)	5.0
13	Ammonia Compressor L. O. Turbine	7.00 (MP)	2.0
Urea Plant			
14	CO_2 Compressor	82.00 (SHH)	77.00
15	Desorber	7.00 (SMH)	6.00
Power Plant			
16	Alternator-I	26.00 (SMH)	7.10
17	Alternator-II	22.00 (SMH)	3.80

STEAM GENERATION & LET-DOWN SYSTEM:

STEAM GENERATION AND LET-DOWN SYSTEM

AMMONIA PLANT, AFCCL

LOG SHEET 2 OF 30

DATE : 19.02.2024.

Weather :

STEAM GENERATOR (52 - 2402) – FLOW / PRESSURE

TIME	WB TO STD 52-2001	SHS FROM STD 52-2001	FUEL G.N. TO STM GEN 52-2402	AIB TO STM. GEN 52-2402	BLOW DOWN FROM STD 52-2001	WB COMMON TEMP. OUTLET 52-2107	SMH TO AIPR COIL 52-2103/1	SMH SUPER HEATER OUTLET 52-2101/1	SMH OUTLET 52-2102/1	FUEL GN TO STM GEN 52-2402	STEAM DRUM 52-2001	SHH TO SILENCER 52-2004	SLS FROM BD FLASH DRUM 52-2301
INSTR.	FRC 101	FR 102	FRC 09	FR 10	FR 12	TI X	FI 03	FI 811	PI 24	PI 20	PR 101	PRC 801	PIC 855
UNIT.	T/H	T/H	NM³/H	NM³/H	T/H	°C	T/H	T/H	Barg	Barg	Barg	Barg	Barg
DESIGN	198	194	8990	88300	2.03	290	4.0	206	40.2	1.0	121.6	109.8	3.1
07-00	188	164	10443	103500	/	416	4.0	120	42.6	.83	127	116	3.4
09-00	188	164	10443	103500	/	416	4.0	120	42.6	.83	127	116	3.4
11-00	186	161	[illegible]	103500		416	4.0	120	42.6	.83	127	116	3.4
13-00	186	164	10442	102350		416	4.0	120	42.6	.83	127	116	3.4
15-00	186	164	10443	103500	✓	417	4.0	120	42.6	.83	127	116	3.4
17-00	186	164	10443	103500	✓	417	4.0	120	42.6	.83	127	116	3.4
19-00	185	164	10443	103500	✓	418	4.0	120	42.6	.83	127	116	3.4
21-00	185	164	10443	103500	✓	219	4.0	120	42.6	.83	127	116	3.4
23-00	188	162	10659	108150	✓	215	4.0	114	42.6	.82	127	115	3.9
01-00	188	162	10659	108150	✓	215	4.0	114	42.6	.82	127	115	3.9
03-00	188	161	10659	108150		215	4.0	114	42.6	.83	127	115	3.9
05-00	188	161	10659	108150	✓	215	4.0	114	42.6	.83	127	115	3.9

STEAM GENERATOR (52 - 2402) – TEMPERATURE

TIME	WB TO PREHEATER 52-2107	WB OUTLET PREHEATER 52-2107	SHS INLET 52-2101/I	SHH OUTLET 52-2101/I	SHH INLET 52-2101/II	SHH OUTLET 52-2101/II	SHH INLET 52-2101/III	SHH OUTLET 52-2101/III	SMH INLET 52-2101/I	SMH OUTLET 52-2102/I	SMH INLET 52-2102/II	SMH OUTLET 52-2101/I
INSTR.	TI-111 / TIC-106	TI-108 / TIC-106	TI 49	TI 50	TI-63 / TIC-51	TI-52 / TR-53	TI-64 / TIC-54	TI-56 / TRC-55	TI 83	TI 84	TI-65 / TIC-57	TI-59 / TR-58
UNIT.	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C
DESIGN	210	275	345	375		425		510	383			505
07-00	191 / 160	325 / 219	/	407	326	425	414	511	383	440	416	503
09-00	191 / 160	322 / 219		407	326	425	414	510	381	440	416	502
11-00	191 / 162	320 / 219	.	407	324	425	414	502	380	440	416	502
13-00	191 / 160	328 / 219		407	324	429	412	502	380	440	414	500
15-00	191 / 160	326 / 219		406	325	428	412	507	380	440	414	504
17-00	192 / 160	326 / 219		406	325	428	412	507	386	440	414	504
19-00	[illegible]	[illegible]	✓	411	325	427	415	510	352	440	414	506
21-00	190 / 160	320 / 219	✓	411	326	428	416	510	356	426	416	506
23-00	186 / 160	319 / 215	✓	413	325	428	415	510	359	432	413	506
01-00	186 / 160	314 / 215	✓	419	325	428	415	510	359	432	413	505
03-00	155 / 155	315 / 215	✓	412	326	427	416	510	362	427	414	505
05-00	155 / 160	319 / 215	✓	412	326	427	416	510	361	432	416	507

LEVEL / ANALYSIS / LET-DOWN SYSTEM (UNIT -52)

TIME	STEAM DRUM 52-2001	STEAM DRUM 52-2001	CONDENSATE DRUM 52-2009	CONDUCTIVITY OF BD FROM STM. DRUM	PH OF BD. WATER	OUTLET SMH LET DOWN 52PV 802	OUTLET SMH LET DOWN MOTOR OP. VALVE	SMH VENT TO SILENCER 52-2004	SLH AFTER LET - DOWN	SLH TO SILENCER 52-2008	SLS AFTER LET DOWN	SLS TO SILENCER 52-2008	SMH AFTER DESUPERHEATER 52-2120	SLS AFTER DESUPERHEATER 52-2123	SLH AFTER DSH 52-2122	SMH AFTER DSH 52-2120	SLH AFTER DSH 52-2122	SLS AFTER DSH 52-2123
INSTR.	LRC 104	LI 105	LIC 112	AR 102	AR 103	PR 802	PR 803	PR 804	PR 805	PIC 806	PIC 807	PIC 808	TI 803	TI 809	TI 810	TR 802	TR 805	TR 807
UNIT.	%	%	%	us/cm		BAR	BAR	BAR	BAR	BAR	BAR	°C	°C	°C	°C	°C	°C	°C
DESIGN	70	70	50	15	9.2	41.2	41.2	38.7	4.5	4.3	3.0	2.9	390	150	200	390	200	144
07-00	64	70	50	–	–	45	40.8	40.8	5.6	5.5	3.2	3.0	372	–	227	/	218	160
09-00	64	70	50	–	–	45	40.8	40.8	5.6	5.5	3.2	3.0	370	–	227	–	218	160
11-00	64	70	50			45	40.8	40.8	5.6	5.5	3.2	3.0	360		227		218	160
13-00	64	70	50	✓	–	45	40.5	40.5	5.6	5.5	3.2	3.0	356	–	225	–	216	160
15-00	62	70	50	✓		45	40.6	40.8	5.4	5.5	3.2	3.0	358	✓	225	✓	216	160
17-00	62	70	50			45	40.8	40.8	5.6	5.5	3.2	3.0	365	–	225	-	216	160
19-00	62	70	50			45	[illegible]	[illegible]	[illegible]	[illegible]	3.2	3.0	377	-	221		[illegible]	160
21-00	62	70	50			45	40.8	40.8	5.5	5.4	3.2	2.8	373	-	207	-	206	160
23-00	64	70	50	=	/	45	40.8	40.8	5.5	5.4	3.4	3.25	384	✓	221		219	157
01-00	64	70	50	✓	/	45	40.8	40.6	5.5	5.4	3.4	3.25	368		221	✓	219	157
03-00	64	70	50			45	40.8	40.6	5.5	5.4	3.4	3.25	368	-	220		217	157
05-00	64	70	50			45	40.8	40.6	5.5	5.4	3.4	3.25	368		220		217	157

MORNING SHIFT :

EVENING SHIFT :

NIGHT SHIFT :

REMARKS

SHIFT IN-CHARGE	SECTION IN-CHARGE	RECORDED BY	SHIFT IN-CHARGE	SECTION IN-CHARGE	RECORDED BY	SHIFT IN-CHARGE	SECTION IN-CHARGE	RECORDED BY
								19.02.24

USING LUBE OIL PROPERTIES:

:

Using Lube Oil in Urea Plant

Sl. No.	Code No.	New Name	Old Name	Using pump & Equipment	Using in particular position
01	91.50.14350	Mobil Nuto H-68	Mobil Hydrolic oil AW-68	33-1101/1102,331121/1122, 33-1181/1182	Powering, Seal oil, Injection pump
02	91.50.34050	Mobil turbine oil DTE-768	Mobil turbine oil -68	33-1105, 33-1123/24, 33-1127/28, 33-1141/42, 33-1173/74, 33-1187/88, 33-1195/96, 33-PV-808, 33-1174/71 (booster pump)	All bearing House
03	91.50.14050	Mobil Nuto H-32	Mobil Hydrolic oil AW-32	33-1125/1126,33-1129/1130, 33-1183/1184,33-1185/86, 33-1189/90, 33-1191/92, 33-1193/94, 33-1121/22, 33-1241(Scrapper)	1. Top Converter 2. Bearing house
04.	91.50.33850	Mobil DTE-746	Mobil Turbine oil -68	Co_2 Compressor oil reservoir	Co_2 Com. lube oil & control oil
05	91.50.16250	Mobil Nuto H-100	Mobil Hydrolic oil AW-100	33-1143/44, 33-1444 (Prill bucket)	Variator bearing
06	91.50.07300	Mobil gear oil-600XP - 150	Mobil gear oil -629	33-1241/71	Driven gear box
07	91.50.07400	Mobil gear oil-600XP - 220	Mobil gear oil -630	33-1101/02, 33-1121/22, 33-1181/82, Co_2 comp. barring gear	reduction gear box, gear box

Various Lube oil properties

Oil name	ISO viscosity grate	Viscosity at 40°C	Density at 15°C	Flash point °C	Pour poin
Mobil Nuto H-68	68	68	0.882	234	-18
Mobil Nuto H-100	100	100	.884	242	-15
Mobil Nuto H-32	32	32	0.872	212	-24
Mobil gear oil-600XP -150	150	150	.89	230	-24
Mobil gear oil-600XP -220	220	220	.89	240	-24
Mobil DTE -746	46	44	.86	230	-30
Mobil turbine oil DTE -768	68	64	.87	242	-30

N.B:(Source) Jamuna Oil Company Ltd.

NH3 COMPRESSOR & TURBINE DATA SHEET :

NH_3 COMPRESSOR and TURBINE (L.O. AND STEAM)
AMMONIA PLANT, A.F.C.C.L. B. BARIA

LOG SHEET 29 OF 30
DATE : February 1, 2024
Weather :

LUBE OIL SYSTEM OF COMPRESSOR

TIME / DESCRIPTION	L.O TO COMP. JOURNAL BEARING FRONT	L.O TO COMP. JOURNAL BEARING REAR	S.O TO SEAL CASING	OIL RETURN FROM STAND STILL SEAL	Δ P OF S.O SUPPLY & L.O. RETURN	Δ P OF SEAL AG AND RETURN L.O OF COMP FRONT	Δ P OF SEAL AG AND RETURN L.O OF COMP REAR	N2 TO OIL ACCUMULATOR	Δ P OF OIL FILTERS	Δ P OF COMP L.O/S.O SUPPLY AND RETURN	MAIN/AUX L.O PUMP DELIVERY	L.O AFTER PDCV-116	L.O RESERVOIR 58-2004	L.O BEFORE COOLER	L.O AFTER L.O COOLERS	WR FROM L.O TURBINE 58-1604	WR FROM OIL COOLERS 58-2107-08	L.O RESERVOIR 58-2004
	PRESSURE												TEMP					LEVEL
INSTR.	PI 178	PI 179	PI 180	PI 181	PDI 182	PDI 183	PDI 184	PI 189	PDI 174	PDI 176	PI 172/173	PI 106/175	TI 165	TI 166	TI 169/105	TI 174	TI 168	LG 105
UNIT.	BARG	BARG	BARG	BARG	BARG	mbar	mbar	BARG	BARG	BARG	BARG	BARG	°C	°C	°C	°C	°C	%
DESIGN	0.6-1.7	0.5-1.7	0.7-1.6	Max-1.6	1.0	50	50	7.0	1.0	3.5	8.0	4.7	60	58	45	45	38	75
07-00	5.2	2.5	4.1		1.1	94	88		.11	3.7	7.9	7.8/8.0	57	48	45		36	51
09-00	5.2	2.5	4.15		1.15	95	90		.11	3.7	7.9	7.8/8.0	57	48	45		36	51
11-00	5.4	2.5	4.2		1.1	95	94		.11	3.7	8.0	7.8/8.0	57	49	46		36	51
13-00	5.7	2.6	4.2		1.15	98	110		.11	3.7	8.1	7.9/8.1	58	49	48		36	51
15-00	5.7	2.6	4.3		1.0	100	95		.12	3.7	8.0	7.9/8.1	58	58	46		36	51
17-00	5.7	2.6	4.3		1.0	100	95		.12	3.7	8.0	7.8/8.0	58	46	45		36	51
19-00	5.8	2.6	4.2		1.1	100	95		.12	3.7	8.0	7.8/8.0	58	49	45		36	51
21-00	5.8	2.6	4.2		1.1	100	95		.12	3.7	8.0	7.8/8.0	58	48	45		36	51
23-00	5.6	2.5	4.2		1.1	90	92		.12	3.7	8.0	7.8/8.0	58	48	45		36	51
01-00	5.6	2.5	4.2		1.1	90	92		.12	3.7	8.0	7.8/8.0	58	48	45		36	51
03-00	5.6	2.5	4.2		1.1	90	92		.12	3.7	8.0	7.8/8.0	58	48	45		36	51
05-00	5.5	2.5	4.2		1.15	90	92		.12	3.7	8.2	7.8/8.0	56	48	45		36	51

TEMPERATURE / TURBINE (58-1601)

TIME / DESCRIPTION	SEAL CASING OF COMPRESSOR FRONT	JOURNAL BEARING OF COMP. FRONT	JOURNAL BEARING OF COMP. REAR	COMPRESSOR THRUST BEARING	JOURNAL BEARING COMPRESSOR FRONT	JOURNAL BEARING OF COMP. REAR	COMP. THRUST BEARING	TURBINE FIRST STAGE PRESSURE	INITIAL STEAM PRESSURE	NOZZLE PRESSURE-I	NOZZLE PRESSURE-II	NOZZLE PRESSURE-III	PREHEATING LINE PRESSURE	INITIAL STEAM TEMP.	EXHAUST STEAM TEMP
	TEMPERATURE							PRESSURE						TEMP	
INSTR.	TI 170	TI 171	TI 172	TI 173	TI 106	TI 108	TI 110	PI 275	PI 276	PI 277	PI 278	PI 279	PI 282	TI 270	TI 271
UNIT.	°C	°C	°C	°C	°C	°C	°C	BARG	BARG	BARG	BARG	BARG	BARG	°C	°C
DESIGN	58	58	58	58	58	58	58	20	38.2		20		38.2	495	40
07-00	53	66	56	50			52	21	39	40	38	20	41		109
09-00	53	66	56	50			52	21	39	40	38	20	41		110
11-00	54	66	56	50			53	21	39	40	37	20	41		110
13-00	55	66	56	50			54	21	39	40	37	20	41		110
15-00	54	67	56	52			53	21	39	40	38	20	41		113
17-00	54	67	56	51			52	21	39	40	38	20	41		113
19-00	54	66	56	52			53	21	39	40	38	20	41		121
21-00	54	66	56	52			51	21	39	40	38	20	41		121
23-00	54	67	55	50			51	22	39	40	38	20	41		125
01-00	54	67	55	50			51	22	39	40	38	20	41		125
03-00	54	67	55	50			51	22	39	40	38	20	41		125
05-00	54	67	55	50			51	22	39	40	38	20	41		125

TURBINE (58-1602) TURBINE (58-1604)

TIME / DESCRIPTION	SMH TO L.O. TURBINE 58-1602	SLH FROM L.O. TURBINE 58-1602	SLH FROM L.O. TURBINE 58-1602	TURBINE SPEED 58-1602	TURBINE SPEED 58-1604	SMH TO L.O. TURBINE 58-1604	SLH FROM L.O. TURB. 58-1604	SLH FROM TO L.O. TURB. 58-1604	SMH TO TURBINE 58-1604
	PRESS		TEMP	SPEED		PRESS		TEMP	
INSTR.	PI 280	PI 281	TI 272	SI 221	SI	PI 170	PI 171	TI 175	TI 176
UNIT.	BARG	BARG	°C	RPM	RPM	BARG	BARG	°C	°C
DESIGN	41.2	3.9	200	2900	1500	41.2	3.9	200	365
07-00									
09-00									
11-00									
13-00									
15-00									
17-00									
19-00									
21-00									
23-00									
01-00									
03-00									
05-00									

REMARKS: MORNING SHIFT : | EVENING SHIFT : | NIGHT SHIFT : A

SHIFT IN-CHARGE | SECTION IN-CHARGE | RECORDED BY | SHIFT IN-CHARGE | SECTION IN-CHARGE | RECORDED BY 01.02.24 | SHIFT IN-CHARGE | SECTION IN-CHARGE Sakib | RECORDED BY

SYNGAS COMPRESSOR & DRIVE TURBINE DATA SHEET:

AMMONIA PLANT
SYN. GAS COMPRESSOR & DRIVE TURBINE (OIL SYSTEM)
A.F.C.C.L.

LOG SHEET 27 OF 30
DATE : 01-02-2024
Weather :

TURBINE

TIME / DESCRIPTION	HP STAGE THRUST & RADIAL BEARING FRONT	HP STAGE RADIAL BEARING REAR	HP & LP STAGE COUPLING	LP STAGE THRUST & RADIAL BEARING FRONT	LP STAGE RADIAL BEARING REAR	LP COMPRESSOR AND TURBINE COUPLING	HP & LP TURBINE COUPLING	COUPLING TURBINE SIDE
	L.O. RETURN TEMPERATURE						L.O. SUPPLY PRESSURE	
INSTR.	TI 152	TI 153	TI 154	TI 155	TI 156	TI 157	PI 160	PI 164 (TURB)
UNIT.	°C	°C	°C	°C	°C	°C	BARG	BARG
DESIGN	107							
07-00	78	81	56	89	83	65	1.25	.4
09-00	78	81	56	89	83	65	1.25	.4
11-00								
13-00								
15-00	79	81	56	89	87	67	1.25	.42
17-00								
19-00	79	81	56	89.5	83	67	1.25	.42
21-00								
23-00	80	81	56	90	84	66.8	1.25	.42
01-00								
03-00	79	81	56	90	83	66	1.25	.42
05-00								

COMPRESSOR

TIME / DESCRIPTION	COUPLING COMPR. SIDE	COUPLING I & II STAGE	COUPLING II & III STAGE	COUPLING III & IV STAGE	L.O. RETURN TO RADIAL BEARING FRONT	SEAL OIL RETURN DISCHARGE	SEAL OIL RETURN SUCTION	L.O. RETURN REAR & THRUST BEARING	L.O. RETURN I & II STAGE COUPLING	L.O. RETURN RADIAL BEARING FRONT	SEAL OIL RETURN DISCHARGE	SEAL OIL RETURN SUCTION
	L.O. SUPPLY PRESSURE				TEMPERATURE: STAGE-I						STAGE-II	
INSTR.	PI 164 (COMP)	PI 169	PI 174	PI 179	TI 158	TI 159	TI 160	TI 161	TI 162	TI 163	TI 164	TI 165
UNIT.	BARG	BARG	BARG	BARG	°C	°C	°C	°C	°C	°C	°C	°C
DESIGN												
07-00	1.2	1.3	1.0	1.0	74	31	80.6	74	82	74	71	55
09-00	1.2	1.3	1.0	1.0	74	31	80.6	74	82	74	71	55
11-00												
13-00												
15-00	1.22	1.3	1.0	1.0	75	31	81.5	75	84	75	73	55
17-00												
19-00	1.22	1.3	1.0	1.0	75	31.5	82	75	84	75	74	55
21-00												
23-00	1.22	1.3	1.0	1.0	76	31	82	76.5	84	76	74	55
01-00												
03-00	1.22	1.3	1.0	1.0	75	31	81.5	76	83	75	73	55
05-00												

COMPRESSOR — TEMPERATURE (continued)

TIME / DESCRIPTION	L.O. RETURN REAR & THRUST BEARING	L.O. RETURN II & III STAGE COUPLING	L.O. RETURN RADIAL BEARING FRONT	SEAL OIL RETURN DISCHARGE	SEAL OIL RETURN SUCTION	L.O. RETURN RADIAL REAR & THRUST BEARING	L.O. RETURN III & IV STAGE COUPLING	L.O. RETURN RADIAL BEARING FRONT	SEAL OIL RETURN RECYCLE SUCTION	SEAL OIL RETURN IV STAGE SUCTION	L.O. RETURN RADIAL REAR & THRUST BEARING
	STAGE-II		STAGE-III					STAGE-IV/RECYCLE			
INSTR.	TI 166	TI 167	TI 168	TI 169	TI 170	TI 171	TI 172	TI 173	TI 174	TI 175	TI 176
UNIT.	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C
DESIGN											
07-00	76	73	72.5	92	86	48	68	/	82	73	88
09-00	76	73	71.5	92	86	48	68		82	73	88
11-00											
13-00											
15-00	76	73	75	92	87	48	69	/	82.5	73	89
17-00											
19-00	76	73	75	92	87	47	69	–	83	79	89
21-00											
23-00	78	73	74	92	87	48	69.5	–	83	73	90
01-00											
03-00	77	73	73	91	86	48	69	–	82	73	89
05-00											

REMARKS: MORNING SHIFT : | EVENING SHIFT : | NIGHT SHIFT :

SHIFT IN-CHARGE | SECTION IN-CHARGE | RECORDED BY 01.02.24 | SHIFT IN-CHARGE | SECTION IN-CHARGE | RECORDED BY | SHIFT IN-CHARGE | SECTION IN-CHARGE Sakib | RECORDED BY

BENFIELD SOLN.& CONDENSATE PUMPS DATA SHEET:

BENFIELD SOLN. & CONDENSATE PUMPS
AMMONIA PLANT, A.F.C.C.L.

LOG SHEET 19 OF 30
DATE : 01.07.2024
Weather :

HP SOLUTION PUMPS (54-1103/04) — PRESSURE

TIME	INLET SOLN.TO EXPN.VALVE 54 LV-14A	OUTLET SOLN OF EXPN.VALVE 54-LV-14A	OUTLET L.O. FILTER	SUCTION SOLN.PUMPS	DELIVETRY OF SOLN PUMPS	OUTLET MAIN L.O.PUMP 54-1113/14/15/16	OUTLET L.O FILTER	BEARING OIL	GLAND SEAL CASING	GLAND SEAL CASING	BEARING OIL	COUPLING OIL
INSTR.	PI 513	PI 514	PI 104/02	PI 520/522	PI 521/23	PI 580/87	PI 582/89	PI 583/90	PI 584/91	PI 585/92	PI 586/93	PI 594/95
UNIT.	Barg	Barg	Barg	Barg	Barg	Barg	Barg	Barg	Barg	Barg	Barg	Barg
DESIGN	27.6	5	5	8.2	35.5	6	5	0.8	12	12	0.8	0.2
07-00	27	2.0		/	38	5.4	4.7	1.0	12	17	1.1	.90
09-00	27	2.0	/	/	38	5.4	4.7	1.0	12	17	1.1	.90
11-00	27	2.0	/	/	38	5.4	4.7	1.0	12	17	1.1	.90
13-00	27	2.0	/	/	38	5.4	4.8	1.0	12	17	1.1	.90
15-00	27	2.0			38	5.4	4.8	1.0	12	17	1.1	.90
17-00	27	2.0			38	5.4	4.8	1.0	12	12	1.1	.90
19-00	27	2.0			38	5.4	4.8	1.0	12	17	1.1	.90
21-00	27	2.0			38	5.4	4.8	1.0	12	17	1.1	.90
23-00	27	2.0			38	5.4	4.7	1.0	12	17	1.2	.90
01-00	27	2.0			38	5.4	4.7	1.0	12	17	1.2	.90
03-00	27	2.0			38	5.4	4.7	1.0	12	17	1.2	.90
05-00	27	2.0			38	5.4	4.7	1.0	12	17	1.2	.90

HP SOLUTION PUMPS (54-1103/04) — TEMPERATURE, LEVEL, MOTOR

TIME	OUTLET MAIN L.O.PUMP54-1113/14/15/16	OUTLET L.O.OF L.O.COOLER	WR FROM L.O.COOLER 54-2110/11	BEARNG OF H.P. SOLN.PUMPS	GLAND SEAL CASING OF H.P.SOLN.PUMPS	GLAND SEAL CASING OF H.P.SOLN.PUMPS	BEARING OF H.P SOLN. PUMPS	MOTOR BEARING OF H.P.PUMPS	MOTOR BEARING FRONT SIDE	LEVEL: RESERVOIR 54-2009/07	MOTOR: 54-1103/04
INSTR.	TI 580/87	TI 581/88	TI 582/89	TI 583/90	TI 584/91	TI 585/92	TI 586/93	TI 595/97	TI 596/98	LG 119/111	AMPS
UNIT.	°C	°C	°C	°C	°C	°C	°C	°C	°C	%	AMPS
DESIGN	50	45	83	50	50	50	50	75	75	75	72
07-00	50	45		50	48	52	50	52	60	80	
09-00	50	45		50	48	52	50	52	60	80	
11-00	50	45		50	48	52	50	52	60	80	
13-00	50	45		50	48	52	50	53	63	80	
15-00	50	45		50	48	52	50	63	56	80	
17-00	50	45		50	48	52	50	63	55	80	
19-00	50	45		50	48	52	50	63	55	80	
21-00	50	45		50	48	52	50	62	55	80	
23-00	50	45		50	48	52	50	60	51	80	
01-00	49	45		50	48	52	50	60	51	80	
03-00	49	45		50	48	52	50	60	51	80	
05-00	49	45		49	47	50	49	49	50	80	

L P SOLUTION PMPS (54-1100/02), COND. PUMP (54-1105/06), EXP. TURB (54-1601)

TIME	LP PRESSURE: SUCTION SOLN	DRLIVERY SOLN	SEAL CASING	SEAL CASING	LP TEMPERATURE: BEARING	SEAL CASING	SEAL CASING	BEARING	MOTOR: 54-1101/02	COND. PUMP PRESS: SUCTION COND PUMPS DELIVERY	COND PUMPS	TEMP: INLET CPG TO PUMPS	MOTOR: 54-1105/06	EXP. TURB PRESSURE	PRESSURE	TEMP
INSTR.	PI 516/18	PI 517/19	PI 570/72	PI 571/73	TI 570/74	TI 571/75	TI 572/76	TI 573/77	AMPS	PI 530/32	PI 531/33	TI 506	AMPS	PI 511	PI 512	TI 502
UNIT.	Barg	Barg	Barg	Barg	°C	°C	°C	°C	AMPS	Barg	Barg	°C	AMPS	Barg	Barg	°C
DESIGN	0.8	8.2	2	2	50	50	50	50	65	0.32	13	50	81	27.6	5.0	113
07-00	.90	8.5	.9	/	35	52	50	32		/	17	55				
09-00	.90	8.5	.9		35	52	50	32			17	55				
11-00	.90	8.5	.9		35	54	50	32			17	55				
13-00	.90	8.5	.9		35	52	50	32			17	55				
15-00	.90	8.5	1.8		40	58	56	35			17	60				
17-00	.90	8.5	1.8		40	58	56	35			17	60				
19-00	.90	8.5	1.8		40	58	56	35			17	60				
21-00	.90	8.5	1.8		40	58	56	35			17	60				
23-00	.90	8.5	1.8		40	58	56	35			17	60				
01-00	.90	8.5	1.8		40	58	56	35			17	60				
03-00	.90	8.5	1.8		40	52	56	35			17	60				
05-00	.90	8.5	1.8		38	56	55	34			17	58				

REMARKS — MORNING SHIFT : | EVENING SHIFT : | NIGHT SHIFT :

SHIFT IN-CHARGE | SECTION IN-CHARGE | RECORDED BY | SHIFT IN-CHARGE | SECTION IN-CHARGE | RECORDED BY | SHIFT IN-CHARGE | SECTION IN-CHARGE | RECORDED BY

CO2 REMOVAL & CONDENSATE STRIPPING DATA SHEET :

CO_2REMOVAL and CONDENSATE STRIPPNG
AMMONIA PLANT, A.F.C.C.L.

LOG SHEET 18 OF 30
DATE : 01.07.2024
Weather :

ABSORBER, DESORBER

TIME	ABSORBER FLOW: WB TO ABSORBER WASH TRAY	PRESSURE: INLET GCV	PRESSURE: OUTLET GCV.SOLN.SEP.54-2303	LEVEL: SOLUTION BOTTOM	DESORBER FLOW: CONDENSATE TO DESORBER WASH TRAY	TEMP: INLET SOLN.REBOILER 54-2102	LEVEL: REBOILER SHELL	LEVEL: DESORBER SOLN.BOTTOM	LEVEL: DESORBER SOLN.TOP
INSTR.	PI	08 PI	507 PI	506 LG	11A/B FI	07 TI	501 LG	07 LG	18A/B LG
UNIT.	TON H	Barg	Barg	% TON	H	°C	%	%	% TON
DESIGN	1.0	27.6	27.4	50	2.0	113	50	50	
07-00		27.2	27	58			100	55	90
09-00		27.2	27	58			100	55	70
11-00		27.2	27	58			100	55	90
13-00		27.2	27.2	58			100	55	90
15-00		27.2	27	58	5.0		100	56	90
17-00		27.2	27	58	5.0		100	56	90
19-00		27.2	27	58	4.0		100	52	90
21-00		27.2	27	58	4.0		100	52	90
23-00		27.2	27	58	4.0		100	55	90
01-00		27.2	27	60	4.0		100	54	90
03-00		27.2	27	60	4.0		100	56	90
05-00		27.2	27	60	4.0		100	55	90

STM GEN & FLUSHDRUM, COND. SEP. & CO_2SEP.

TIME	FLOW: SLS FROM STM. GEN.TO EJECTOR 54-2305	PRESSURE: INLET GCV TO STM GEN 54-2101	STEAM GENERATOR SHELL	SLS TO EJECTOR FROM STM.GEN.	SLS TO EJECTOR FROM FLUSH	TEMP: INLET GCV TO STEAM GENERATOR	LEVEL: STEAM GENERATOR	LEVEL: SOLUTION FLUNH DRUM	OUTLET CO2 FROM COND.SEP.#.54-2307	INLET CO2 TO COND.SEP.-I 54-2304	LEVEL: SEPARATOR-I 54-2301	SEPARATOR-II 54-2302	COND.SEPARATOR-1 54-2304	COND.SEPARATOR-II 54-2307
INSTR.	20 FI	12 PI	501 PI	503 PI	526 PI	540 TI	503 LG	01/02 LG	22 PI	539 TI	504 LG	04 LG	08 LG	24 LG
UNIT.	H	Barg	Barg	Barg	Barg	°C	%	%	Barg	°C	%	%	%	%
DESIGN	21.8	28.4	3.7	3.7	.06	225	50	50	.23	78	50	50	50	50
07-00		27.5	3.1	/	.03	225	50	70	/	/	50	55	40	60
09-00		27.5	3.1	/	.03	225	50	70			50	55	40	60
11-00		27.5	3.1	-	.03	225	50	70			50	55	40	60
13-00		27.5	3.1	-	.03	225	50	70			50	55	40	60
15-00		27.5	4.3	4.2	.03	225	50	70			54	60	40	60
17-00		27.5	4.3	4.2	.03	225	57	70			54	60	40	60
19-00		27.5	4.3	4.2	.03	225	45	66			54	60	40	52
21-00		27.5	4.3	4.2	.03	225	45	65			54	60	40	52
23-00		27.5	4.3	4.2	.03	225	45	65			54	60	40	52
01-00		27.5	4.3	4.2	.03	225	45	66			54	60	40	52
03-00		27.5	4.3	4.2	.03	225	45	64			54	60	40	52
05-00		27.5	4.3	4.2	.03	225	45	66			54	60	40	52

CONDENSATE STRIPPING (UNIT-50) — FLOW, PRESS, TEMPERATURE, LEVEL, VALVE

TIME	FLOW: OUTLET SOLN.FILTER 54-2306	PRESS: ΔP SOLN FILTER 54-2306	OUTLET WR FROM CO2 COOLER 2108	SOLN STORAGE TANK 54-2001	OUTLET CO2 AIR COOLER 54-2105	OUTLET WB FROMWB PREHEATER 54-2107	OUTLET CO2 AIR COLLER 54-2105	LEVEL: STORAGE TANK 54-2001	VALVE: WB BY PASS OF 54-2007	VALVE: OUTLET WB FROM WB PREHEATER 54-2107
INSTR.	26 FI	09 PDI	10 TI	507 TI	508 TI	510 TI	511 TI	512 LI	30 HV	07 HV
UNIT.	M³/H	Barg	°C	°C	°C	°C	°C	MTR OPEN	% OPEN	%
DESIGN	50		45	80	60	127	60 MIM	2M		0.3
07-00	/	/	✓	/	55	/	/	/	45	80
09-00					55				45	80
11-00					55				45	80
13-00					55				45	80
15-00					55				45	80
17-00					55				45	80
19-00					55				45	80
21-00					55				45	80
23-00					55				45	80
01-00					55				45	80
03-00					55				45	80
05-00					55				45	80

CONDENSATE STRIPPING (UNIT-50) — PRESSURE, TEMP

TIME	VENT FROM COND STRIPPER 50-2201	INLET STRIPPED COND PUMP 50 1101/02	OUTLET STRIPPED COND PUMP 1102/01	COND STRIPPER BOTTOM	VPC VENT TOP OF STRIPPER	VPC VENT FROM STRIPPER	STRIPPED COND PUMPS 50-1101/02 SUCTION	VPC FROM REBOILER TO STRIPPER	COND EXIT PREHEATER 50-2101	ΔP ABSORBER	
INSTR.	08 PI	501 PI	503/04 PI	505/06 PI	507 PI	502 TI	501 TI	502 TI	504 TI	503 PDI	
UNIT.	Barg	Barg	Barg	Barg	Barg	°C	°C	°C	°C	Mbr	
DESIGN	0.8	3.7	0.42	0.3	107	82	110	93	200		
07-00	/	/	5.1	/	95	/	105	/	/	155	
09-00			5.1		95		105			135	
11-00			5.1		95		105			135	
13-00			5.1		95		105			135	
15-00			5.4		95		105			150	
17-00			5.4		95		105			150	
19-00			5.4		95		105			150	
21-00			5.4		95		105			150	
23-00			5.4		95		105			150	
01-00			5.4		9.5		105			150	
03-00			5.4		9.5		105			150	
05-00			5.4		9.5		105			150	

REMARKS — MORNING SHIFT : | EVENING SHIFT : | NIGHT SHIFT :

SHIFT IN-CHARGE | SECTION IN-CHARGE | RECORDED BY | SHIFT IN-CHARGE | SECTION IN-CHARGE | RECORDED BY | SHIFT IN-CHARGE | SECTION IN-CHARGE | RECORDED BY

DESULFURIZATION & REFORMING DATA SHEET:

DESULFURIZATION & REFORMING
AMMONIA PLANT, A.F.C.C.L.

LOG SHEET 16 OF 30
DATE: 01.02.24
Weather:

TIME	GN METERING (87-UNIT) LEVEL: GN K.O. DRUM 87-2003	FLOW: TURBINE METER 01A/01B	PRESS: GN INLET TO 87-2003	PRESS: ΔP ACROSS FILTER 87-2001/2002	PRESS: GN FILTER OUTLET	DESULFURIZATION (51-UNIT) FLOW: TOTAL FUEL GN	FLOW: DGR INLET GN	FLOW: DGR OUTLET GN	FLOW: STEAM TO IRF	FLOW: HYDROGENATION GAS	PRESSURE: OUTLET GN PREHEATER 51-2101	PRESSURE: SLH TO GN PREHEATER	PRESSURE: FUEL GN DISTRIBUTION HEADER	PRESSURE: DOWN STREM GN OF 51-PV-02	PRESSURE: HYDROGENATION GAS TO DGR	PRESSURE: DGR OUTLET GN	PRESSURE: ΔP ACROSS DGR	TEMP: OUTLET GN PREHEATER 51-2102	TEMP: FUEL GN DISTRIBUTION HEADER	TEMP: HYDROGENATION GAS	FLOW: FUEL GN TO IRF BURNERS	FLOW: PROCESS GAS TO FUEL
INSTR.	LG 01	FQI 01/A/B	PI 01	PDI 02/03	PI 09	FI 09	FI 02	FI 04/05	FI 06/07	FI 03	PI 502	PI 503	PI 78	PI 505	PI 504	PI 509/05	PDI 04	TI 503	TI 82	TI 501	FI 05	FI 06
UNIT.	%	NM³	BAR	mbar	BAR	NM³ HR	NM³ HR	NM³ HR	TON HR	NM³ HR	Barg	Barg	Barg	Barg	Barg	Barg	Barg	°C	°C	°C NM³	HR NM³	HR
DESIGN	10	52625	41.2		43.2	23350	26156	27485	81.2	1735	42.2	2.9	3.0	40.2	61.2	37.6	0.3	103	90	43	7474	7319
07-00	✓	✓	42	16	42.4	6.5	5.2	5.1	70	3.0	40	1.8	3.8	34.5	60	35	.15	70	56	36	5.1	1.5
09-00	✓	✓	42	16	42.4	6.5	5.2	5.1	70	3.0	43	1.8	3.8	34.5	60	33	.18	70	56	36	5.1	1.5
11-00	✓	·	41.4	160	42.0	6.5	5.2	5.1	70	3.0	43	1.8	3.8	34.5	60	33	.18	70	56	36	5.1	1.5
13-00	✓	✓	41.2	160	41.8	6.5	5.2	5.1	70	3.0	43	1.8	3.8	34.5	60	33.8	.18	70	56	36	5.1	1.5
15-00																						
17-00	Busy for Temperature Adjustable Work																					
19-00	–	–	39.[illegible]	158	40.5	6.4	5.2	5.7	72	3.1	41.0	1.8	3.7	34.8	60	33.8	0.18	67	56	38	5.1	1.5
21-00	–	–	39.5	158	40.5	6.4	5.2	5.7	72	3.1	41	1.8	3.7	34.5	60	33.8	0.18	67	56	38	5.1	1.5
23-00	–	–	39.5	158	40.5	6.4	5.2	5.7	72	3.1	41	1.18	3.7	34.8	60	33.8	.18	63	56	38	5.1	1.5
01-00	–	–	39.5	158	40.5	6.4	5.2	5.7	72	3.1	39.8	1.18	3.7	34.8	60	33.8	.18	63	56	38	5.1	1.5
03-00	–	✓	39.5	158	40.5	6.4	5.2	5.7	72	3.1	39.8	1.18	3.7	34.6	60	33.8	.18	63	56	38	5	1.5
05-00	–	–	39.5	158	40.5	6.4	5.2	5.7	72	3.1	39.8	1.18	3.7	34.8	60	33.8	.18	63	56	38	5	1.5

TIME	1 RF (52-2401) PRESSURE: FUEL GN TO BURNERS	IGNITION GN TO PILOT BURNERS	FUEL GCV	FUEL GT (FUEL GAS TO IRF	BURNERS)	FURNACE 52-1401	GNP TO IRF	ΔP ACROSS IRF	FLOW: AIPR TO PREHEATER 52-2103/1	FLOW: WB TO 2RF JACKET	2 RF (52-2201) PRESSURE: CRACKED GAS TO 2RF	2RF JACKET WATER	OUTLET P.G COOLER PROCESS GAS	ΔP ACROSS 2RF & PGC	WB TO PREHEATER 52-2107	AIPR TO 2RF BEFORE VALVE	LEVEL: 2RF JACKET WATER	FLOW: COND. PUMPS DELIVERY	CONDENSATE TEMP: COND PUMP (52-1110/52-1111) SUCTION	COND. PUMP (52-1110/52-1111) DELIVERY	UTILITY CONDS TO DRUM (52-2009)	LEVEL: CONDENSATE DRUM
INSTR.	PI 13	PI 15	PI 16	57-PI 517	PI 17/79	PI 03	PI 31/36	PDI 22	FI 01/02	FI 103	PI 151	PI 152	PI 153	PI 153/151	PI 154	PI 156A/B	LI 101/02	FI 105	PI 157/59	PI 158/60	PI 161	LG 111/12
UNIT.	Barg	Barg	Barg	Barg	Barg	mmhg	Barg	Barg	NM³/H	NM³/H	Barg	Barg	Barg	Barg	Barg	Barg	% TON	H	Barg	Barg	Barg	%
DESIGN	2.9	0.4	27.5	38.2	1.1	-3	35.4	3.55	36710	1.0	31.85	1.25	31.0		125	33.3	80	38.7	0.1	8.5	0.1	50
07-00	3.9	.15	26	✓	5.0/3.0	.6	30.5/32.6	1.3	5.7	.8	300	1.15	29.2	.8	115	29	100	22	35	11	–	60/55
09-00	39	"	28	✓	5.5/3.0	.6	30.5/32.0	1.3	5.7	.8	300	1.15	29.4	.8	118	29	100	24	35	11	–	60/55
11-00	3.9	"	28	–	5.8/3.0	.6	30.5/32.0	1.3	5.7	.8	300	1.15	29.2	.8	115	29	100	23	35	11	–	60/55
13-00	3.9	"	28	✓	5.8/3.0	.6	30.5/32.0	1.3	5.7	.8	30	1.15	29.2	.8	118	29	100	23	35	11	✓	60/55
15-00																						
17-00	Work																					
19-00	3.92	"	29.0	·	9.5/3.2	.60	30.2/31.5	1.3	5.8	0.80	30.2	1.15	29.9	0.80	118	29	98	23	35	10.4	–	60/55
21-00	3.92	"	29.0	–	9.5/3.2	.60	30.2/31.5	1.3	5.8	0.80	30.2	1.15	29.7	0.80	115	29	98	23	35	10.6		60/55
23-00	3.92	"	29	–	10/3.2	.6	30.2/31.5	1.3	5.8	.80	30.2	1.15	29.7	.80	119	29	98	30	35	10.6	–	60/55
01-00	3.9	"	29	–	10/3.2	.6	30.2/31.5	1.3	5.8	.80	30	1.15	29.2	.80	119	29	98	30	35	10.8	–	60/55
03-00	3.9	"	29	–	10/3	.5	30.2/31.5	1.05	5.8	.80	30	1.15	29.2	.80	119	29	98	30	35	10.8	–	60/55
05-00	3.9	"	29	–	10/3	.5	30.2/31.5	1.05	5.8	.80	30	1.15	29.2	.80	119	29	98	30	35	10.8	–	60/55

REMARKS

MORNING SHIFT: C — 52-1111 oil makeup

EVENING SHIFT: D

NIGHT SHIFT: A

SHIFT IN-CHARGE		SECTION IN-CHARGE		RECORDED BY		SHIFT IN-CHARGE		SECTION IN-CHARGE		RECORDED BY		SHIFT IN-CHARGE		SECTION IN-CHARGE		RECORDED BY	

COMPRESSORS(PROCESS) DATA SHEET:

COMPRESORS (PROCESS)
AMMONIA PLANT, A.F.C.C.L.

LOG SHEET 8 OF 30
DATE: 01.02.2024
Weather:

TIME	(AIPRCOMP (52-1003) PRESS: FINAL DELIVERY (AIPR)	FLOW: FINAL DELIVERY (AIPR)	FLOW: SMH TO TURBINE 52-1601	ANTI SURGE SET POINT INDICATOR	SPEED: SPEED CONTROLLER P.A. TURBINE	SPEED: TURBINE SPEED	VALVE: ANTI SURGE MANUAL CONTROL	SYN GAS COMPRESSOR (56-1001) FLOW: MAKE-UP GAS FLOW COMP.SUCTION	FLOW: RECYCLE GAS FLOW	FLOW: SMH TO TURBINE INTER STAGE 56-1601	FLOW: SHH INLET TO TURBINE 56-1601	INLET SEPARATOR PRESSURE 56-2301	PRESSURE: SYN.GAS COMP.STAGE IV OUT LET	PRESSURE: OUT LET SYN GAS COMP RECYCLE STAGE	PRESSURE: RECYCLE GAS PRESS 56-HV-04	PRESSURE: SYN GAS COMP OUTLET STAGE-IV	ANTISURGE SET POINT	SPEED: TURBINE SPEED 56-1601	VALVES: ANTI SURGE MANUAL CONTROL	VALVES: RECYCLE STAGE BY PASS MANUAL CONTROL	SPEED CONTROL
INSTR.	PI 306A	FI 306A	FR 401	XI 306	HIC 402A	SI 404	HIC 306	FI 01B	FI 02B	FR 202	52FR 802	PI/PR 03B	PI/PR 11B	PI 12B	PI 61	PR 01	XI 01	SI 301	HIC 01B	HIC 10B	HIC 301B
UNIT.	0.6 BARG	6000 NM³/H	TON/H		%	RPM	%	16740 NM³/H	68960 NM³/H	5640 TON/H	23.7 TON/H	BARG	BARG	BARG	BARG	BARG		RPM	%	%	%
DESIGN	34.3	36710	29.3			8900		110500	460200	33.1	195.1	26.8	299	312.7	312.7	297		13210			
07-00								6.6	6.5	5.8	7.5		5.4	5.8		56					
9-00	34.2	37200	30.2	100	/	8667	/	110484	448290	32712	177.75	25	216	232	240	224	5.8	12625	52	78	—
1-00									5.7												
1-00	34.8	36650	30.4	100	/	8686	/	110404	397070	32.7	177.7	25	220	236	240	224	5.8	12555	52	78	/
-00		6.2x						6.5x	5.7x	5.6x	7.4x		5.6x	6x	6.2x	5.7x					
-00	34.8	37250	30.0	100	/	8725	—	108810	393088	31.6	175.4	25	224	240	248	228	6.0	12502	51.5	78	/
00																					
00	34.2	37200	30.0	100		8737		108810	448180	32.7	177.75	25	224	240	249	228	6.0	12625	52	78	
00		6.0x						6.5x	5.6x	5.7x	7.5x		5.6x		6.1x	5.7x					
0	34.8	36600	30.0	100	/	8710	/	108810	386176	32.1	177.75	25	224	240	244	228	5.7	12655	51.5	77.5	/
[illegible]		6.1x						6.6x	5.6x						6.1x						
[illegible]	34.8	36600	30.0	100	/	8760	/	110484	386176	32.1	177.75	25	224	236	244	228	5.7	12585	51.5	77.5	/

TIME	NH₃ COMPRESSOR (58-1001) FLOW: SMH TO TURB 58-1601	FLOW: FINAL DELIVEY	PRESSURE: COMPRESSOR 1ST STAGE SUCTION	PRESSURE: COMP. 2ND STAGE SUCTION	PRESSURE: COMP. 2ND STAGE DISCHARGE	PRESSURE: NH3 RECEIVER 58-2003	TEMPERATURE: INTERSTAGE COOLER OUTLET A.G. 58-2003	TEMPERATURE: NH3 RECEIVER 58-2003	TEMPERATURE: COMP 1ST.STAGE SUCTION	TEMPERATURE: COMP SUCTION 2ND STAGE	TEMPERATURE: COMP 2ND STAGE DISCHARGE	TEMPERATURE: COMP 1ST STAGE DISCHARGE	NH3 GAS TE.MP NH3 RECEIVER 58-2003	VALVE: ANTI SURGE MANUAL CONTROL	VALVE: NH₃ FLASH DRUM 58-2001	VALVE: NH₃ FLASH DRUM 58-2002	VALVE: NH₃ RECEOVER 58-2003	SPEED: SPEED CONTROL	SPEED: TURBINE SPEED	ANTI SURGE SET POINT INDICATOR
INSTR.	FR 101	FI 108	PI 102-A	PI 103-A	PI 108	PIC 16	TI 15	TI 17	TI 103A	TI 104A	TI 112A	TI 113A	TIC 16	HIC 108	LIC 05	LIC-08 LG-08	LIC 11	HIC 202A	SI 234	XI 108
UNIT.	TON/H	NM³/H	Barg	Barg	Barg	Barg	°C	°C	°C	°C	°C	°C	°C	%	%	%	%	°C	RPM	
DESIGN	15.5	42968	1.26	7.3	16.16	16.16	55	41	-10	20	106	114	MAX45		30	35	50		10090	
07-00																				
9-00	18.6	45000	1.4	7.9	16.2	16.1	80	40	-7.2	37.8	95	110	—	—	06	31	56	—	9320	3.8
1-00																				
1-00	18.0	45000	1.4	7.9	16.2	16.1	47	40	-7.4	36	96	110	–	–	06	32	56	–	9301	3.8
-00	6.1x	4.9x			5.5x															
-00	18.9	44000	1.5	8.1	16.5	16.6	79	41	-7.0	35	97	110		/	11	36	55	/	9293	3.85
00	6.4	4.6			5.6															
00	19.2	44200	1.45	8.0	16.8	16.6	78	40	-7.5	35	97	110			11	35	55	–	9285	3.85
00		4.8x			5.5x															
0	19.2	43200	1.45	8.0	16.5	16.5	78	42	-7.5	36	97	108		/	08	30	56	/	9352	3.[illegible]
[illegible]	6.4x																			
[illegible]	19.2	43200	1.45	7.9	16.5	16.5	80	41	-8.2	37	97	107		/	07	30	57	/	9345	3.9

MORNING SHIFT: 'C'

EVENING SHIFT: "D"

NIGHT SHIFT: "A"

SHIFT IN-CHARGE		SECTION IN-CHARGE		RECORDED BY		SHIFT IN-CHARGE		SECTION IN-CHARGE		RECORDED BY		SHIFT IN-CHARGE		SECTION IN-CHARGE	Sakib	RECORDED BY	

ANNEXURE 3: RULE OF THUMB (ROT) USED IN ANALYSIS

1. 1% gas can be saved for every 20°C rise of air temperature.
2. 1 kg of natural gas requires 17 kg of air for combustion. If we include 5% of excess air, itshould be 17.85 Kg air for burning properly 1 kg of natural gas.
3. The conversion efficiency of heat exchanges (Economizer, air pre-heaters, recuperatoretc. is 60-65%)
4. Replacement of T8 light by T5 lights saves Energy by 25%.
5. Heat rate of waste heat recovery power plant is 4,000 Kcal/kWh.
6. The cost of waste heat recovery power plant is 100 million BDT/MW
7. Pl. add one BDT/kWh towards capital cost, financing charge, O & M etc. while calculating cost of kWh generation from gas generators.
8. In a compressor reduction of one discharge pressure by one kg/cm^2 normally saves power by 9-10 %.
9. 1 Ton AC requires 3,000 kcal /hr.
10. Increase in feed water temp by 6°C reduces fuel consumption by 1%.
11. 10% reduction in excess air improves Boiler efficiency by 1%.
12. Waste Heat Boiler (WHB) produces 500 kg steam per 1,000 kW heat input.
13. Insulation cost is BDT 10,000 per square meter for HVAC system.
14. Cost of high efficiency motor with inverter is BDT 2,200 per kW power rating.
15. Cost of VFD/Inverter is BDT 10,000 per kW power rating.
16. Energy management can save up to 2% of the overall energy consumed by the plant.
17. Every 1°C increase in the set temperature of air conditioner reduces the power consumption by 3%
18. Every one percent reduction in oxygen in flue gas will reduce gas consumption by 1%
19. Every 1 bar reduction in compressed air pressure reduces the power consumption by 8%

Annexure 4: Portable Instruments Used for Measurements

No	Description	Manufacturer	Model Name	Quantity
1	Ultrasonic Flow Meter	Endress Hauser	Prosonic DMTF (M+L)	01 set
2	Thermo-Hygrometer	TESTO	TESTO 625	01 pc
3	Combustion Air Analyzer	TESTO	TESTO 320	01 set
4	Infrared Temperature Meter	KIMO	KIRAY100	01 pc
5	Power Quality Analyzer	HIOKI	PW3198	01 set
6	Thermal Imaging Camera	FLIR	C8940	01 pc
7	Thermometer (Digital) with Surface Probe	TESTO	TESTO 925	01 set
8	Lux Meter	HIOKI	FT3424	01 pc
9	Thermo- Anemometer	CEM	DT-618	1 set
10	AC Clamp current meter	HIOKI	CM3280-10F	01 pc

Figure: HGF motor technical datasheet.

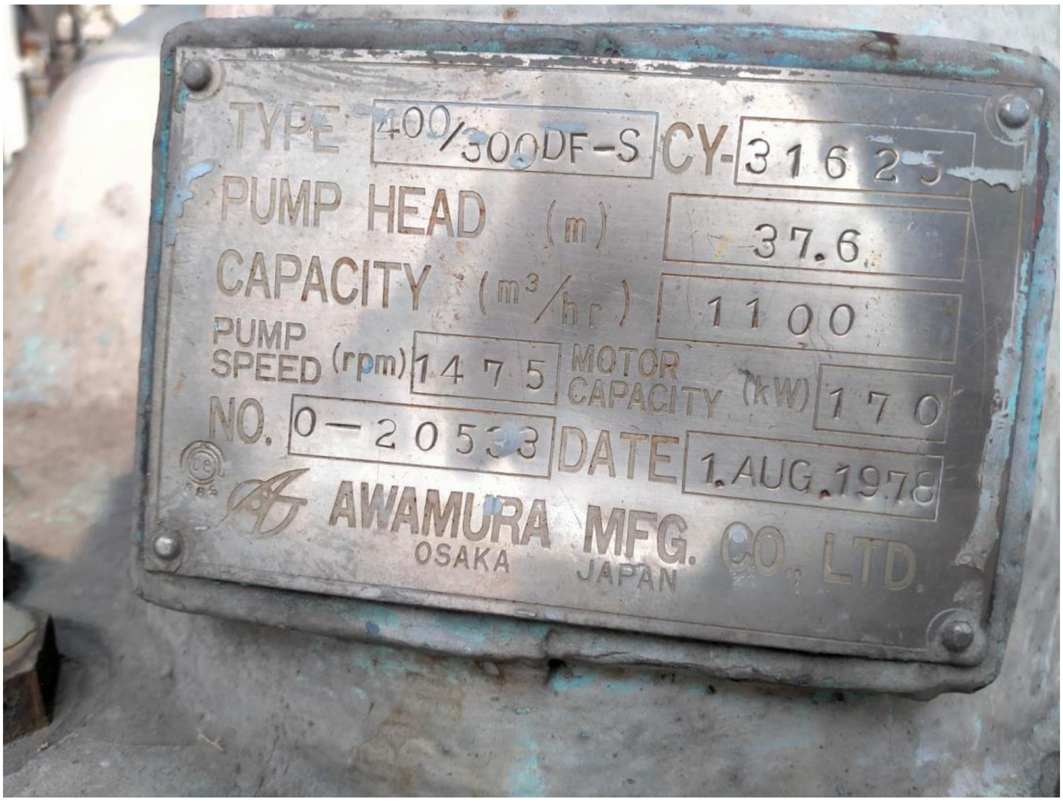


Figure: Circulating Water Pump technical datasheet.

Figure: Condensate Pump technical datasheet.

ANNEXURE 6: PROCESS FLOW DIAGRAM

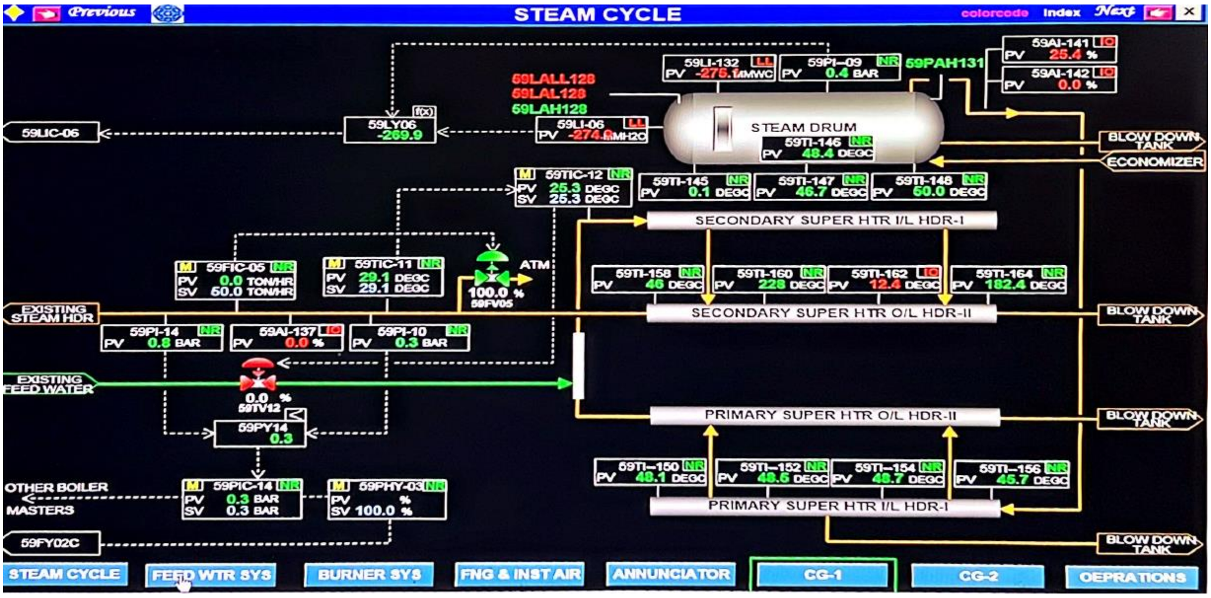


Figure: Process diagram of Steam Cycle

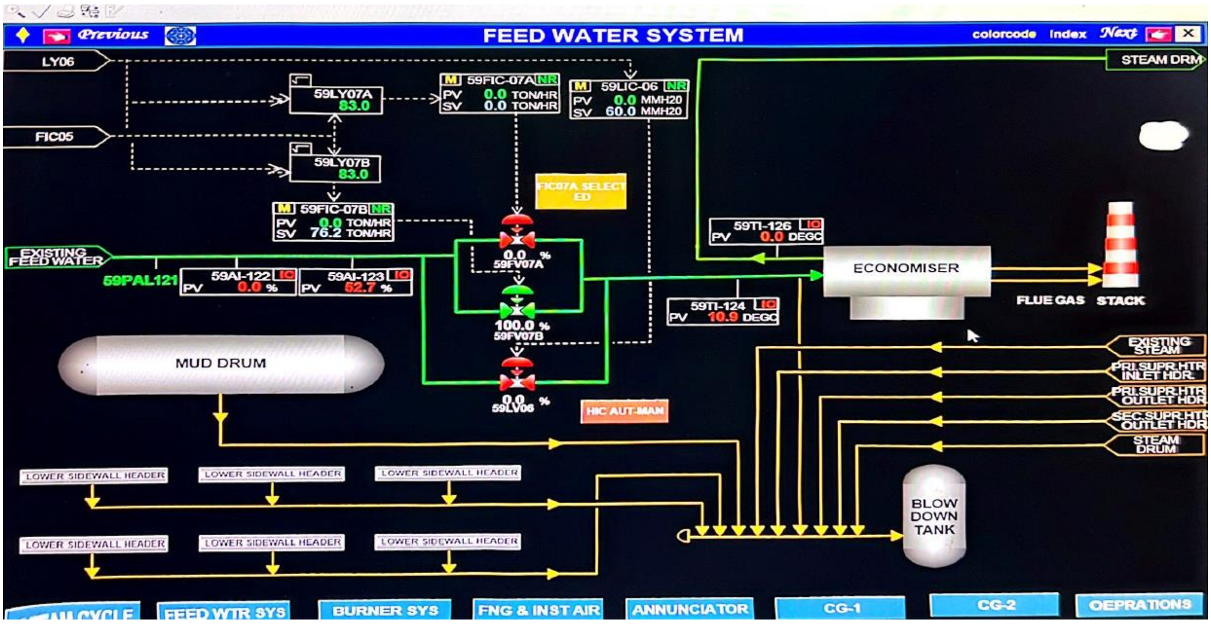


Figure: Outline diagram of Feed Water System

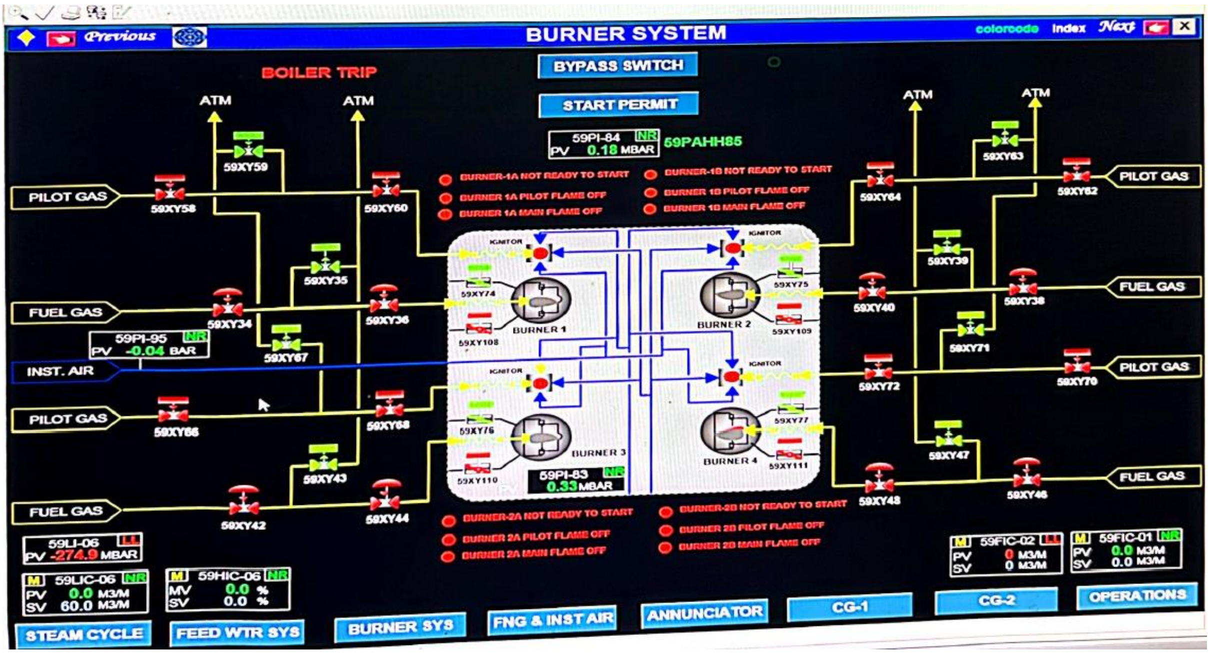


Figure: Outline diagram of Burner System

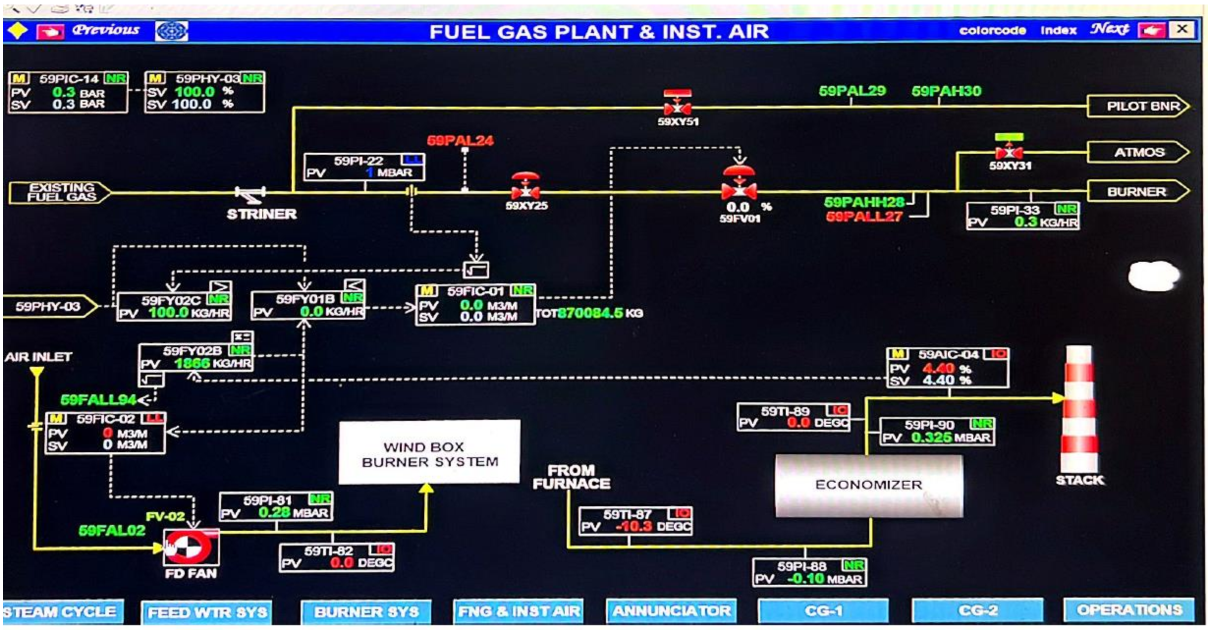


Figure: Outline diagram of Fuel Gas Plant & Instrument Air System

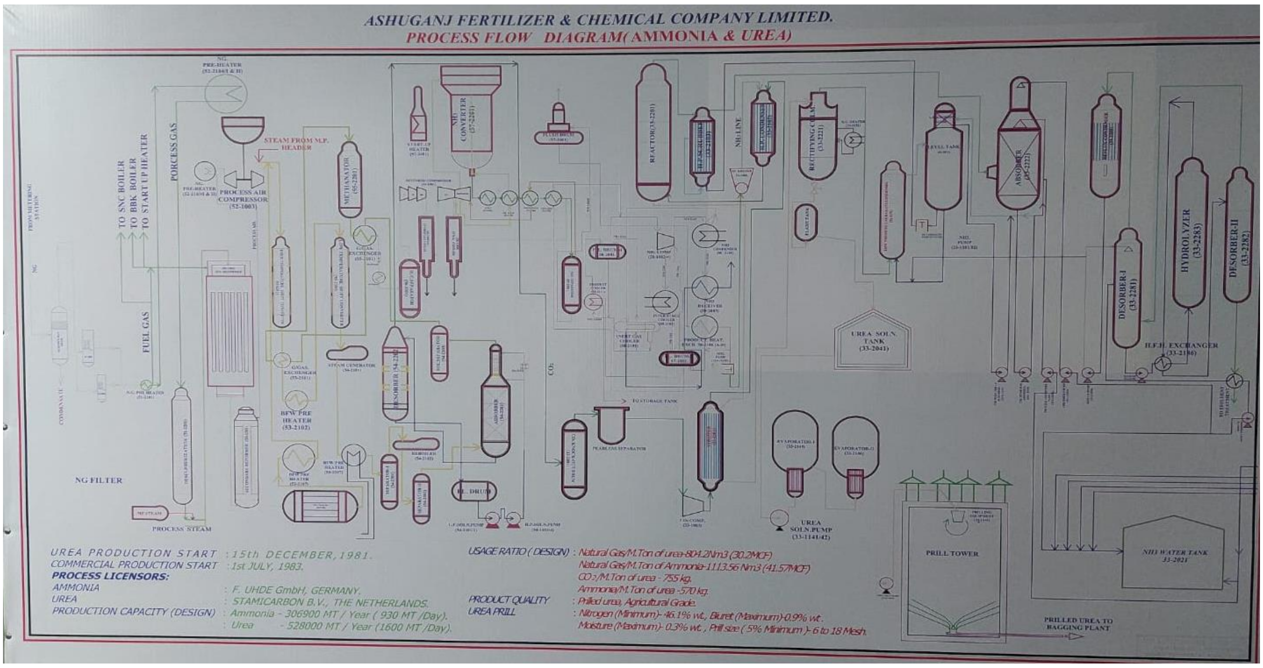


Figure: Process flow diagram of NH_3 & Urea Plant

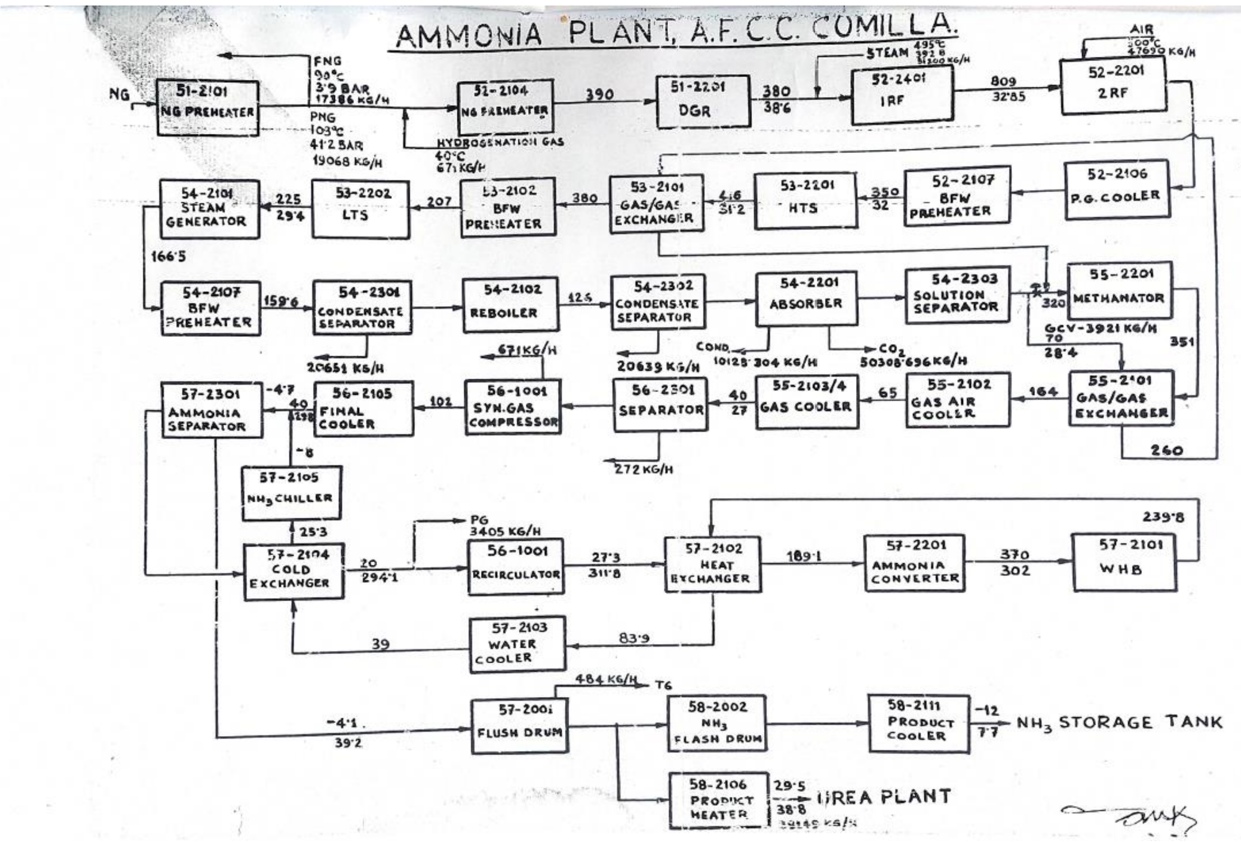
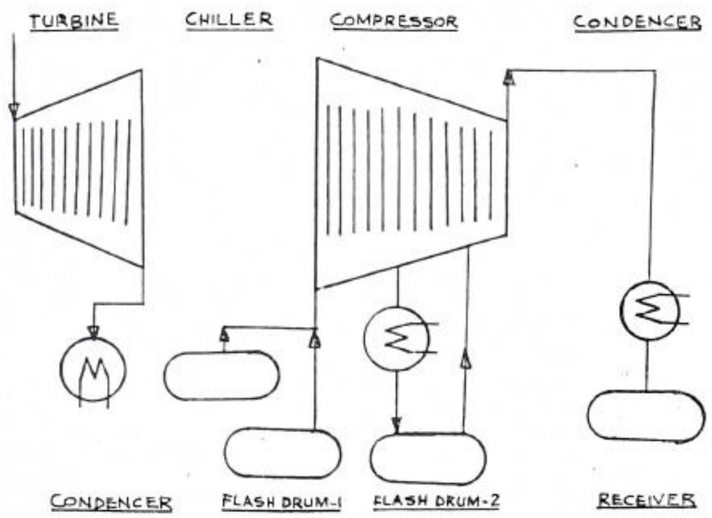


Figure: Block diagram of AMMONIA PLANT.

AMMONIA COMPRESSOR

58-1001



COMPRESSOR DRIVER TURBINE

Manufacturer	:	AEG Kanis
Turbine output at cupling	:	4,000 KW.
Turbine Speed	:	10,090 rpm.
Prohibited Speed Range	:	3,000 - 4,500 rpm.
Life Steam Flow	:	25 t/h
Life steam temperature	:	495 °C
Life steam pressure	:	39.2 bar abs.

COMPRESSOR:

Manufacturer : GHH

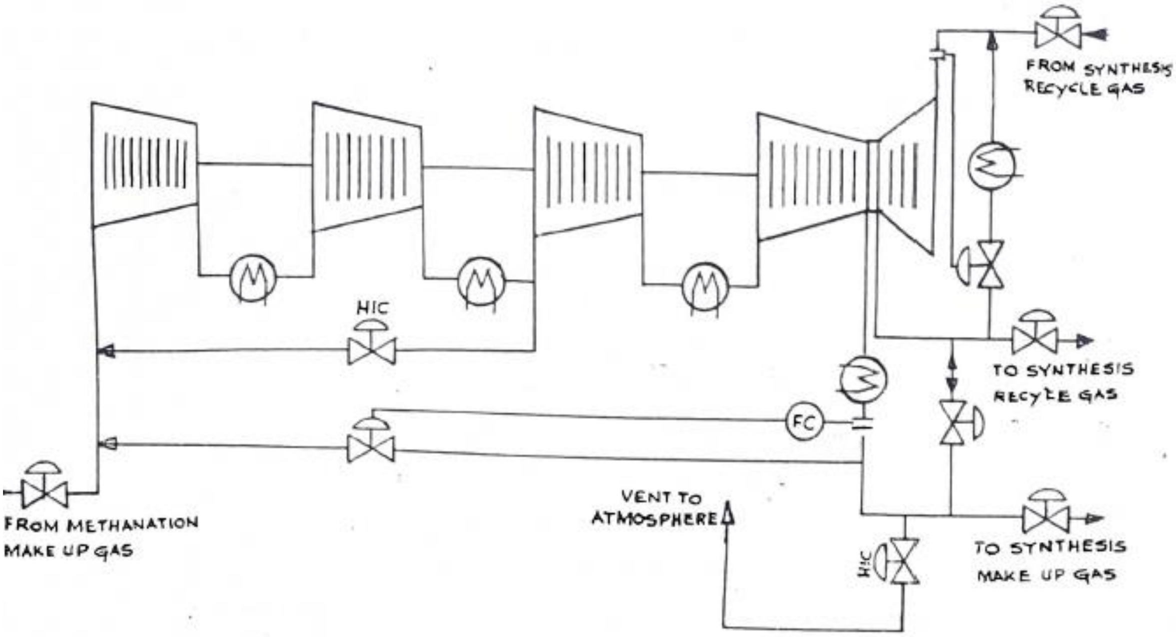
Nature of gas : NH_3

	Stage I		Stage II	
	Suc.	Dis.	Suc.	Dis.
Volume M^3/h	17890	-	5720	-
Temp. °C	- 10	114	20	106
Press. bara	2.26	8.31	8.062	17.16

Normal Speed : 10,090 rpm.

Figure: Schematic Diagram of Ammonia Compressor.

SYNTHESIS GAS COMPRESSOR
56-1601



Type : Centrifugal Compressor
Four Stage + One Recycle Stage.

Manufacturer : Nuovo Pignone, Italy.

Compressor Coupling Power: 18010 KW

Speed : 13210 rpm.

Fluid Handle : Synthesis gas, Molecular Wt. : 8.67

Operating Condition

Stage	I		II		III		IV		R	
	In	Out	In	Out	In	Out	In	Out	In	Out
Flow, Kg/H	42765		42094		42094		42094		223672	
Capacity NM^3/H	110503		108768		108768		108768		460200	
Press. Bara	27.8	63.91	62.65	138.82	136.57	215.55	212.74	302	294.1	313.1
Temp. °C	40	164	43	169	43	116	43	102	20	28

Figure: Schematic Diagram of SYNTHESIS GAS Compressor.

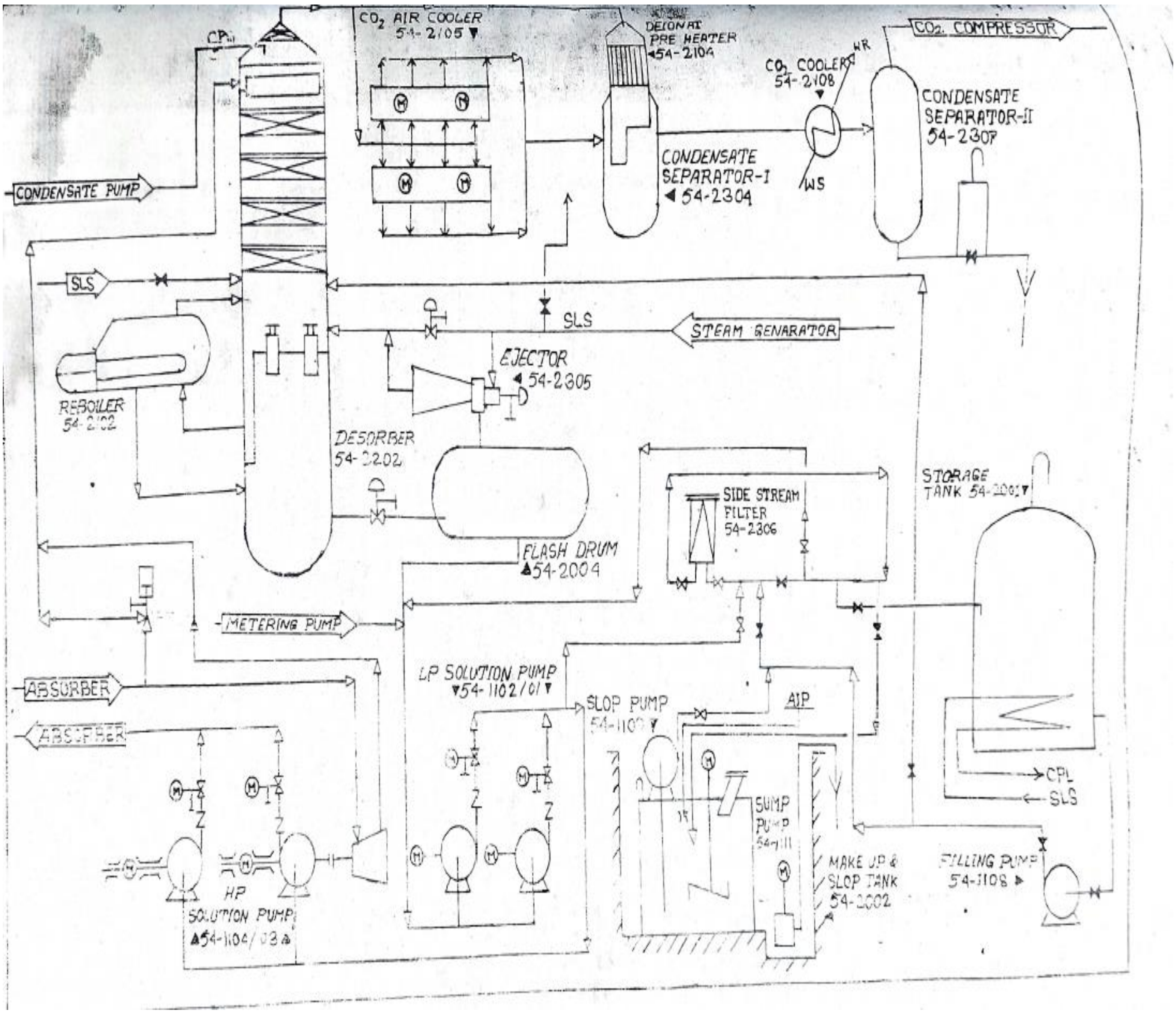
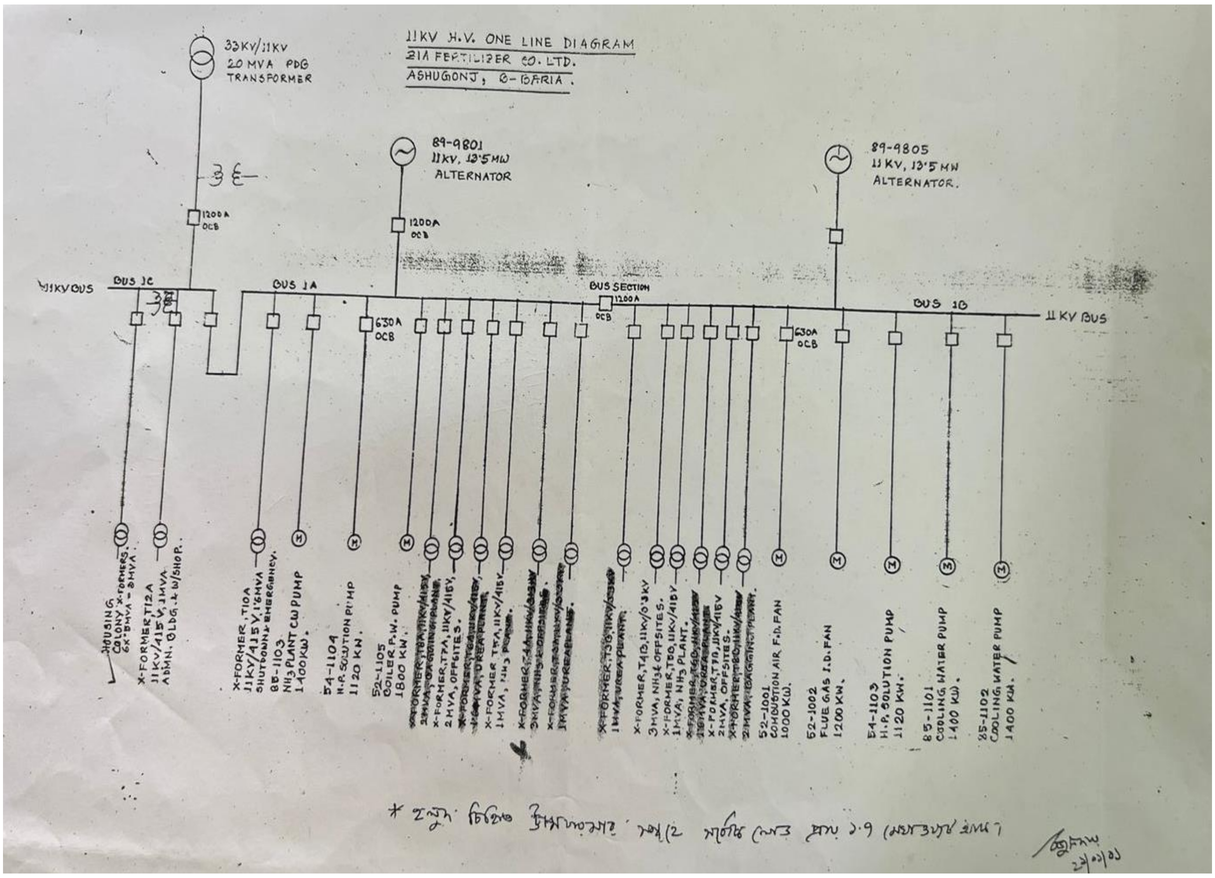


Figure : Process Flow Diagram of Absorption of CO2

ANNEXURE 7: SINGLE LINE DIAGRAM



Annex D

Energy Audit Reports of KAFCO

Energy Audit Report

of

KAFCO

Karnaphuli Fertilizer Company Limited

Rangadia, Karnaphuli, GPO Box # 1010, Chattogram-4000, Bangladesh

Prepared by

Sustainable and Renewable Energy Development Authority (SREDA)

SREDA
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ACKNOWLEDGMENT

The Sustainable and Renewable Energy Development Authority (SREDA) and the Energy Auditor Team extend their heartfelt appreciation to the senior management team and other officials of Karnaphuli Fertilizer Company Limited (KAFCO) for granting the privilege to conduct an energy audit at their facility. SREDA and the Energy Auditor Team acknowledge the invaluable assistance provided by the technical staff in executing the audit. Special thanks are extended to the team for promptly providing the necessary information, which greatly facilitated the energy audit process. Gratitude is also expressed for the engaging discussions, generous support, and enjoyable moments shared during the visits to KAFCO. The collaborative spirit and cooperation demonstrated by the entire team significantly contributed to the success of this audit.

DISCLAIMER

This Energy Audit Report has been prepared through the collaboration of Sustainable and Renewable Energy Development Authority (SREDA) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The purpose of this report is to assess and analyse the energy consumption and efficiency of the Karnaphuli Fertilizer Company Limited Company (KAFCO)'s factory at Chittagong based on the information gathered during the audit process.

This energy audit is conducted in accordance with industry standards and best practices. The assessment includes a review of the facilities of Ammonia plant, Urea Plant, Utility Section, Water Treatment Process, Conveyor System, and the Effluent Treatment Plant. The audit team analyse the energy consumption patterns of the entire facility. The findings and recommenddations provided in this report are based on the information available at the time of the audit. It is important to note that the accuracy and effectiveness of the audit are contingent upon the data provided by the client and the conditions observed during the site visit. Factors such as changes in occupancy, equipment usage, and external influences can impact the actual energy performance of the facility. The recommendations outlined in this report are based on current conditions and assumptions. Any changes to the facility, equipment, or operational practices may affect the accuracy and applicability of these recommendations.

The SREDA, GIZ, and their affiliations and representatives are not liable for any direct, indirect, incidental, consequential, or special damages, losses, or expenses arising out of the use of or reliance upon the information provided in this report.

The KAFCO is responsible for implementing the recommendations outlined in this report. SREDA, GIZ or the energy audit team are not responsible for the client's decisions or actions taken as a result of this audit. This report is provided in good faith, and every effort has been made to ensure its accuracy.

N. B. If you have any queries regarding this report, please contact us within three months from the issuing date of this report.

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ABBREVIATIONS

CO	Carbon Mono Oxide
CO_2	Carbon Dioxide
KAFCO	Karnaphuli Fertilizer Company Limited
DG	Diesel Generator
ECM	Energy Conservation Measure
EMS	Energy Management System
FRP	Fiberglass Reinforced Plastic
GCV	Gross Calorific Value
GEG	Gas Engine Generator
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
HC	Hydrocarbons
IGV	Inlet Guide Vane
IRR	Internal Rate of Return
kW	Kilowatt
kWh	Kilowatt Hour
MJ	Mega-joule
MMSCF	Million Standard Cubic Feet
MSCF	Thousand Standard Cubic Feet
MT	Metric Ton
MTPD	Metric Ton per Day
NG	Natural Gas
NPV	Net Present Value
O&M	Operation and Maintenance
PRF	Primary Reformer
RH	Relative Humidity
SEC	Specific Energy Consumption
SREDA	Sustainable and Renewable Energy Development Authority
STG	Steam Turbine Generator
VFD	Variable Frequency Drive
WHR	Waste Heat Recovery

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EXECUTIVE SUMMARY

Enhancing energy efficiency is recognized as the swiftest and most economical approach to tackle issues related to energy security, the environment, and the economy. Improvements in energy efficiency involve lowering the energy consumption associated with a specific service or level of activity.

The factory's total energy consumption was assessed, revealing the relation between the annual production and the specific energy consumption. This includes natural gas as feed, natural gas as fuel and other energy sources. The energy-intensive urea production process was scrutinized. Opportunities for optimizing equipment efficiency and streamlining operational procedures were identified.

ES.1 Ammonia Production and Specific Energy Consumption

Table ES.1: Energy Consumption Benchmark for Ammonia Production

Financial Year	Average Ammonia Production per Year (1000×T)	Average Specific Energy Consumption (GJ/T)	Average Specific Energy Consumption (MSCF/T)	Corresponding Excess Ammonia for Sale (1000×T)
2017-2018 to 2022-2023	359.24	33.93	34.09	70.97

ES.2 Urea Production and Specific Energy Consumption

Table ES.2: Energy Consumption Benchmark for Urea Production

Financial Year	Average Urea Production per Year (1000×T)	Average Specific Energy Consumption (GJ/T)	Average Specific Energy Consumption (MSCF/T)
2017-2018 to 2022-2023	507.52	24.82	25.07

ES.3 Technical and Financial Assessment of the Energy Conservation Measures

Table ES.3: Technical and Financial Assessment of the Energy Conservation Measures

Energy Conservation Measures (ECMs)	Investment Cost	Annual Savings			Payback Period, Years	Project Lifetime, Years	NPV, BDT	IRR, %
	Cost, BDT	Gas, Nm^3	Energy, GJ	Financial, BDT				
ECM-1: **Energy Saving Scope by Refurbishing or Modifying Feed Water Economizer**	80,000,000.00	21,736,816.20	296,636.95	478,209,956.41	0.17	15	3,172,936,691.90	597.01
ECM-2: **Heat Recovery by covering with Thermal Insulation of the Uninsulated Steam Valve and Flanges (For per m^2 of Insulation)**	4,241,160.00	1,233,071.37	33,646.80	27,127,570.23	0.16	10	149,035,662.04	639.63
ECM-3: **Reformer and Auxiliary Boiler of NH_3 Surface Heat Loss Reduction**	Energy Auditor's team recommends consulting with the process licensors about the energy wastage issue on this region.							
ECM-4: **Installation of Inlet Guide Vane (IGV) at the Inlet of Air Compressor for Controlling the Air Intake**	3,000,000.00	99,132.90	2,705.68	2,180,923.74	1.38	15	11,853,976.07	72.72

Energy Conservation Measures (ECMs)	Investment Cost	Annual Savings			Payback Period, Years	Project Lifetime, Years	NPV, BDT	IRR, %
	Cost, BDT	Gas, Nm³	Energy, GJ	Financial, BDT				
ECM-5: **Installation of Rooftop Solar Panel**	50,000,000.00	-	-	7,568,901.90	6.61	25	9,363,950.53	14.64
ECM-6: **Energy Conservation by Replacing the Cooling Tower's Aluminum Fans with Fiberglass Reinforced Plastic (FRP) Fans**	1,500,000.00	13,058.05	356.40	287,277.14	5.22	15	456,605.67	17.43

The table below shows the ECMs in terms of high-cost, medium cost and low cost ECM:

Energy Conservation Measures (ECMs)	Type of Investment	Investment Cost	Annual Savings			Payback Period, Years	Project Lifetime, Years	NPV, BDT	IRR, %
		Cost, BDT	Gas, Nm³	Energy, GJ	Financial, BDT				
Energy Saving Scope by Refurbishing or Modifying Feed Water Economizer	High	80,000,000.00	21,736,816.20	296,636.95	478,209,956.41	0.17	15	3,172,936,691.90	597.01

Energy Conservation Measures (ECMs)	Type of Investment	Investment Cost	Annual Savings			Payback Period, Years	Project Lifetime, Years	NPV, BDT	IRR, %
		Cost, BDT	Gas, Nm³	Energy, GJ	Financial, BDT				
Installation of Rooftop Solar Panel	High	50,000,000.00	-	-	7,568,901.90	6.61	25	9,363,950.53	14.64
Heat Recovery by covering with Thermal Insulation of the Uninsulated Steam Valve and Flanges (For per m² of Insulation)	Medium	4,241,160.00	1,233,071.37	33,646.80	27,127,570.23	0.16	10	149,035,662.04	639.63
Installation of Inlet Guide Vane (IGV) at the Inlet of Air Compressor for Controlling the Air Intake	Medium	3,000,000.00	99,132.90	2,705.68	2,180,923.74	1.38	15	11,853,976.07	72.72
Energy Conservation by Replacing the Cooling Tower's Aluminum Fans with Fiberglass Reinforced Plastic (FRP) Fans	Low	1,500,000.00	13,058.05	356.40	287,277.14	5.22	15	456,605.67	17.43

ECM-1: Refurbishing or Modifying Feed Water Economizer

- This measure provides the **highest NPV (BDT 3,172,936,691.90)** and an exceptional IRR of 597.01%.
- With a **payback period of just 0.17 years**, it generates immediate and long-term energy savings.
- **Recommendation:** Implement immediately due to its profound impact on financial savings and energy efficiency.

ECM-2: Thermal Insulation for Steam Valve and Flanges

- The IRR of **639.63%** highlights its exceptional profitability.
- Its **low investment cost (BDT 4,241,160.00)** and **payback period of 0.16 years** make it a highly attractive option.
- **Recommendation:** Deploy immediately across all uninsulated areas to prevent heat loss.

ECM-3: NH_3 Reformer and Auxiliary Boiler Heat Loss Reduction

- **Recommendation:** Energy Auditor's team highly recommends to consult with the process licensors about the energy wastage issue on this region.

ECM-4: Installation of Inlet Guide Vane (IGV) for Air Compressors

- Provides an IRR of **72.72%** with a **reasonable payback period of 1.38 years**.
- The investment cost is minimal (BDT 3,000,000.00), and it ensures efficient air intake for compressors.
- **Recommendation:** Implement immediately to improve compressor energy efficiency.

ECM-5: Installation of Rooftop Solar Panels

- Although the payback period is longer (**6.61 years**), this measure offers **sustainable energy generation for 25 years**.
- Its moderate IRR (**14.64%**) reflects long-term profitability and environmental benefits.
- **Recommendation:** Prioritize as part of a long-term sustainability strategy.

ECM-6: Replacing Cooling Tower Fans with FRP Fans

- A low-cost measure (**BDT 1,500,000.00**) with a **payback period of 5.22 years** and IRR of **17.43%**.
- **Recommendation:** Implement to achieve incremental energy efficiency improvements in cooling systems.

CHAPTER 1: ENERGY AUDIT AT KAFCO AND PRODUCTION PROCESSES

1.1 INTRODUCTION

In pursuing sustainable practices and enhancing energy efficiency within electricity and heat-intensive facilities, including power plants and industrial complexes, SREDA and GIZ jointly organized the "**Advanced Hands-on Training on Energy Audit and Energy Auditing for Benchmark Development of Fertilizer Industries**". This program took place at Karnaphuli Fertilizer Company Limited (KAFCO) in Chittagong, Bangladesh, in 2024, from July 50 to July 11.

KAFCO is one of the supreme Chemical Engineering oriented factories in Bangladesh. It is a joint venture factory of Bangladesh, Japan, Denmark and the Netherland. The plant is located at Chittagong. It was first incorporated as a public limited company in 16th July 1981. In 1994 the plant was commissioned and went for its first test run. At the preliminary stage of production, they had encountered several problems and had to shut down the plant frequently. The general contractor of KAFCO had taken some initiatives within the warranty period and replaced several equipment and machineries to resolve the issues. After that the plant was running very well, financial condition got improved and finally all the loans were repaid in 2005-06. In financial year 2008-2009, KAFCO achieved record production of 711,064 MT Urea. From then, they have been able to run the plant with a good margin of profit. The percentage of ownership is depicted in Figure 1.

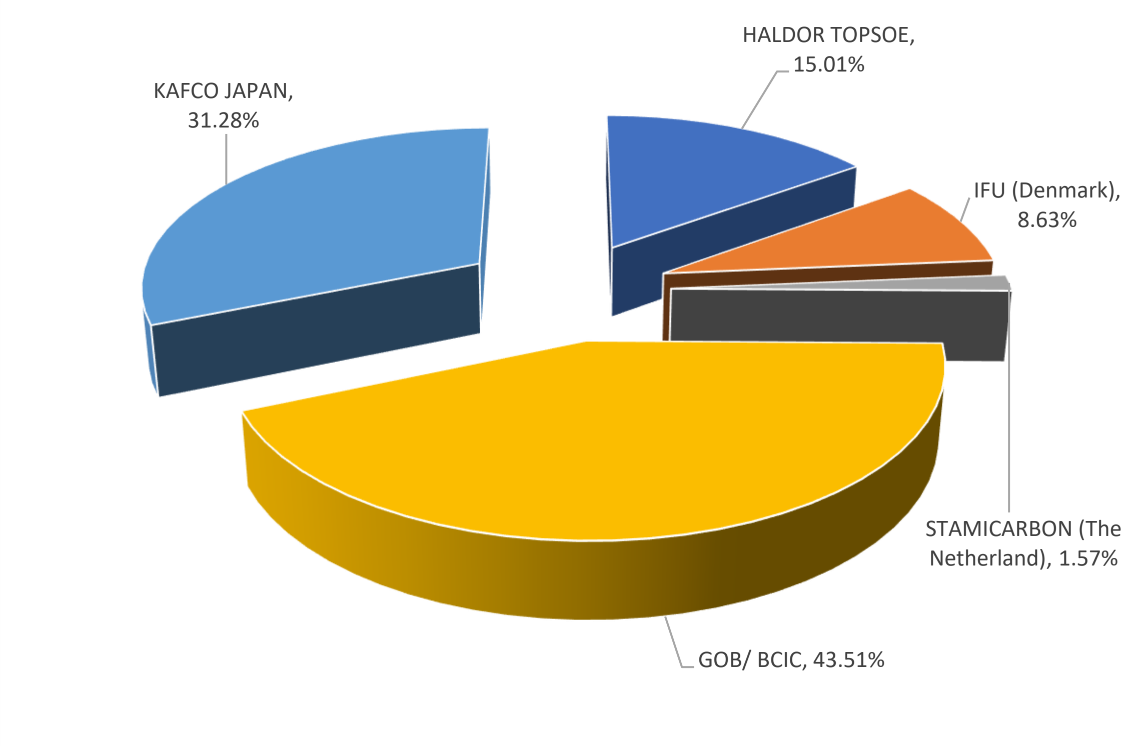


Figure 0.1: The Percentage of Ownership of KAFCO

The whole production process of Urea consists of three plants: The Ammonia (NH3) Plant, The Urea Plant and The Utility Plant. The design capacity of NH3 and urea plants are 1500 and 1725 MT/day respectively. KAFCO has achieved the highest capacity @ 109% ammonia load and 120% urea load, but the actual production mainly depends on adequate gas supply throughout the year. KAFCO sells the excess ammonia to nearby DAPFCL through pipeline on deemed export basis as well as exports by cryogenic ship on case-to-case basis when DAPFCL does not require ammonia. After every three/four years, KAFCO is shut down and attends overhauling.

Bangladesh is an agricultural land and therefore it has an immense demand of fertilizer. Though KAFCO was established as an export-oriented company, currently it does not export any urea to abroad due to Government restrictions for having higher demand in the domestic market. KAFCO sells its entire urea product to BCIC on deemed export basis.

Acknowledging the need for an energy efficiency and conservation approach, SREDA and GIZ took the initiative to showcase the untapped potential for energy savings and establish an energy benchmark in Bangladesh's fertilizer industries. This led to the implementation of an energy audit at KAFCO. A team of certified energy auditors conducted the audit during the specified period, aiming to improve the energy efficiency (EE) of the factory through a combination of technical and organizational measures. The envisioned outcomes include not only lower energy costs but also a reduction in CO2 emissions. This initiative underscores the commitment of SREDA, GIZ, and KAFCO to propel the fertilizer industry towards sustainable and energy-efficient practices, aligning with broader environmental and economic goals.

This background sets the stage for the subsequent audit report, which will delve into the findings, recommendations, and potential avenues for further improvements identified during the energy audit at KAFCO. In Figure 2, the location of KAFCO is illustrated.

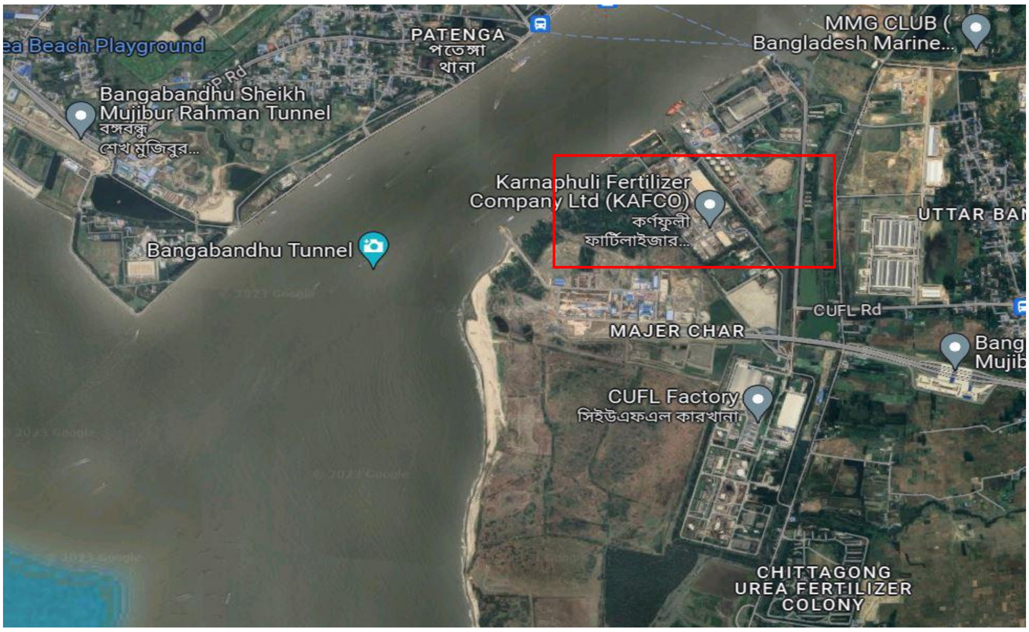


Figure 0.2: Location of KAFCO

1.2 OBJECTIVES OF THE ENERGY AUDIT

The objective of the energy audit at KAFCO is to systematically assess and analyze the energy consumption patterns and efficiency of various processes within the facility. The primary goals of conducting an energy audit in this context include:

i. Identifying Energy Consumption Patterns

ii. Determine the efficiency of energy use in various processes and identify areas where energy is being wasted.

iii. Identify opportunities for reducing energy costs by optimizing energy consumption, improving efficiency, and implementing cost-effective energy-saving measures.

iv. Identify opportunities for reducing carbon emissions.

v. Recommend upgrades to existing technologies or equipment to enhance energy efficiency.

vi. Promote awareness among employees about energy conservation and efficiency.

vii. Identify any potential risks associated with energy consumption, including safety concerns and reliability issues.

By achieving these objectives, the fertilizer factory can enhance its overall energy performance, reduce operational costs, and contribute to sustainability goals.

1.3 Scope of Energy Audit

The scope of an energy audit at KAFCO is comprehensive and involves a detailed examination of energy consumption, production processes, and potential areas for improvement. Here are key aspects included in the scope of the energy audit in fertilizer factory:

i. Overall Energy Consumption Analysis and Benchmarking: Assess the total energy consumption of the facility, including electricity, natural gas, and other energy sources. Break down energy consumption by different processes and operations within the factory.

ii. Process Energy Analysis: Evaluate the energy intensity of key production processes involved in urea manufacturing.

iii. Examine the efficiency of equipment such as compressors, pumps, boilers, and steam turbines.

iv. Utility Systems Evaluation: Analyze the efficiency of utility systems, including steam and electricity generation.

v. Examine the energy efficiency of ammonia synthesis, which is a key precursor in urea production.

vi. HVAC and lighting systems assessment.

vii. Explore opportunities for capturing and utilizing waste heat generated during various processes. Recommend strategies for implementing waste heat recovery systems to improve overall energy efficiency.

viii. Evaluate the efficiency of process control systems and instrumentation.

ix. Identify opportunities for optimizing control strategies to enhance energy performance.

x. Assess the effectiveness of existing energy management practices within the facility. Recommend improvements in energy monitoring, reporting, and management systems.

xi. Conduct a life cycle cost analysis for potential energy-saving measures. Estimate the rough initial investment and assess the financial feasibility with respect to long-term operational and maintenance costs.

xii. Explore opportunities for integrating renewable energy sources, such as solar into the facility's energy mix.

xiii. Evaluate the environmental impact of the facility's energy consumption, with a focus on carbon emissions and other pollutants.

1.4 METHODOLOGY

Based on the scope of work, the following steps were followed during the Energy Audit:

- A field survey was conducted towards the collection of existing operational information and data pertaining to the project area.
- Secondary data was collected from factory concerns. Assigned Engineers, supervisors, and operators for machines were involved in the process while collecting data.
- The technical aspects of the existing facilities were understood and noted down to be analyzed later. It was necessary to analyze any further possible energy-efficient methods or techniques to follow.
- Potential power-consuming sources were identified.
- Catalogs of different machines were collected.
- To collect periodic consumption data, bills, monthly and yearly reports were accumulated.
- On the basis of collecting relevant data, identification of potential impacts has been done using the checklists method.
- Measuring power through different sensor-based devices.

1.5 Factory Description

The general information about KAFCO is presented in Table 1.5.1 and Table 1.5.2.

Table 0.1: Factory Construction Overview

General Contractor	Chiyoda Corporation, Japan
Type of Contract	Lump Sum Trunkey (LSTK) Basis
Financial Sources	Govt. of Bangladesh, KAFCO-Japan (JICA, Marubeni, Chiyoda), Haldor Topsoe A/S, IFU, CDC, Stamicarbon Bv.
Capital Invest/Project Cost	Approximately 600 Million USD
Year of Establishment	KAFCO Incorporated as a Private Limited Company on 16th July 1981
Construction Period	1990-1994
Commercial Production Date	Commercial Production Declared to NBR in June 1995
Total Area	100 Acres
Daily Requirement of Raw Material and Utility	
NG Total	60 MMSCF (100% Load)
Electricity	340 MWh
Water (Make-Up)	15,000 MT

Table 0.2: Capacity of the Key Auxiliary Facility

Auxiliary/Ancillary/Special Facilities	
Power Generation (STG)	2×10 MW
Emergency Power Generation	1×5 MW, 1×4 MW, 1×1 MW
Ammonia Storage	20,000 MT
Bulk Urea Storage	80,000 MT
Nitrogen Unit	400 Nm^3/h
Packaged Boiler	2×95 MT/h
Demi Water Unit	200×3 MT/h
Water Storage	17,500 MT

Auxiliary/Ancillary/Special Facilities	
Bagging Plant	2,200 MT/day
Instrument Air Compressor	2000×2 Nm^3
Ship Loader	500 MT/h
Workshop	Machining/Fabrication

1. PRODUCTION PROCESSES

As stated before, KAFCO's major processes can be classified into three major sections: production of ammonia, production of urea, and utility. The list of process licensors is depicted in the following table.

Table 0.3: Process licensors of KAFCO

Plant	Process Licensor
Ammonia	Haldor Topsoe (Denmark)
Urea	Stamicarbon (Netherlands)
CO_2 Removal	UOP (USA)
Granulation Unit	Hydro Gari (Norway)

1.6.1 AMMONIA PRODUCTION PROCESS

The primary raw material for urea production is ammonia. Ammonia is synthesized through the Haber-Bosch process, which involves the reaction of nitrogen and hydrogen under high pressure and temperature in the presence of a catalyst.

Purpose of ammonia plant: The purpose of ammonia plant is to produce the anhydrous liquid ammonia which will be mainly consumed as the feed of Urea plant and/or will be sent to the liquid ammonia storage facility in accordance with situation. This plant also produces the gaseous carbon dioxide as a byproduct which will be also consumed as the feed stock of Urea plant.

Brief description of process and catalyst: Ammonia is produced from a mixture of hydrogen (H2) and nitrogen (N_2) where the ratio of H_2 and N_2 should be 3 to 1. Besides these two compounds, the mixture will contain inert gases to a limited degree, such as argon (Ar) and methane (CH_4). For ammonia plant, the source of H_2 is hydrocarbon in the form of Natural Gas. The source of N_2 is atmospheric air. The process which are necessary for producing ammonia from the abovementioned raw materials are as follows:

- Sulphur contained in the hydrocarbon feed is completely removed in the desulphurization section.
- The desulphurization hydrocarbon is reformed together with steam and air to raw synthesis gas. This gas contains hydrogen and nitrogen as well as carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), and argon (Ar). The reforming takes place at about 35 kg/cm^{2}g.
- In the gas purification section, CO is first converted into CO_2 and H_2 with steam in order to increase the H_2 yield. CO_2 is then removed in the CO_2 removal section and the remaining CO and CO_2 are converted to methane afterwards in the Methanation section.
- In the ammonia synthesis section, the purified synthesis gas is, after compression to a pressure about 130 kg/cm^{2}g, converted into ammonia by a catalyst reaction.
- The ammonia plant is designed to produce 1500 MPTD ammonia. Most of the produced ammonia is sent to the Urea Plant for urea production. The remaining is sent to the atmospheric storage tank.

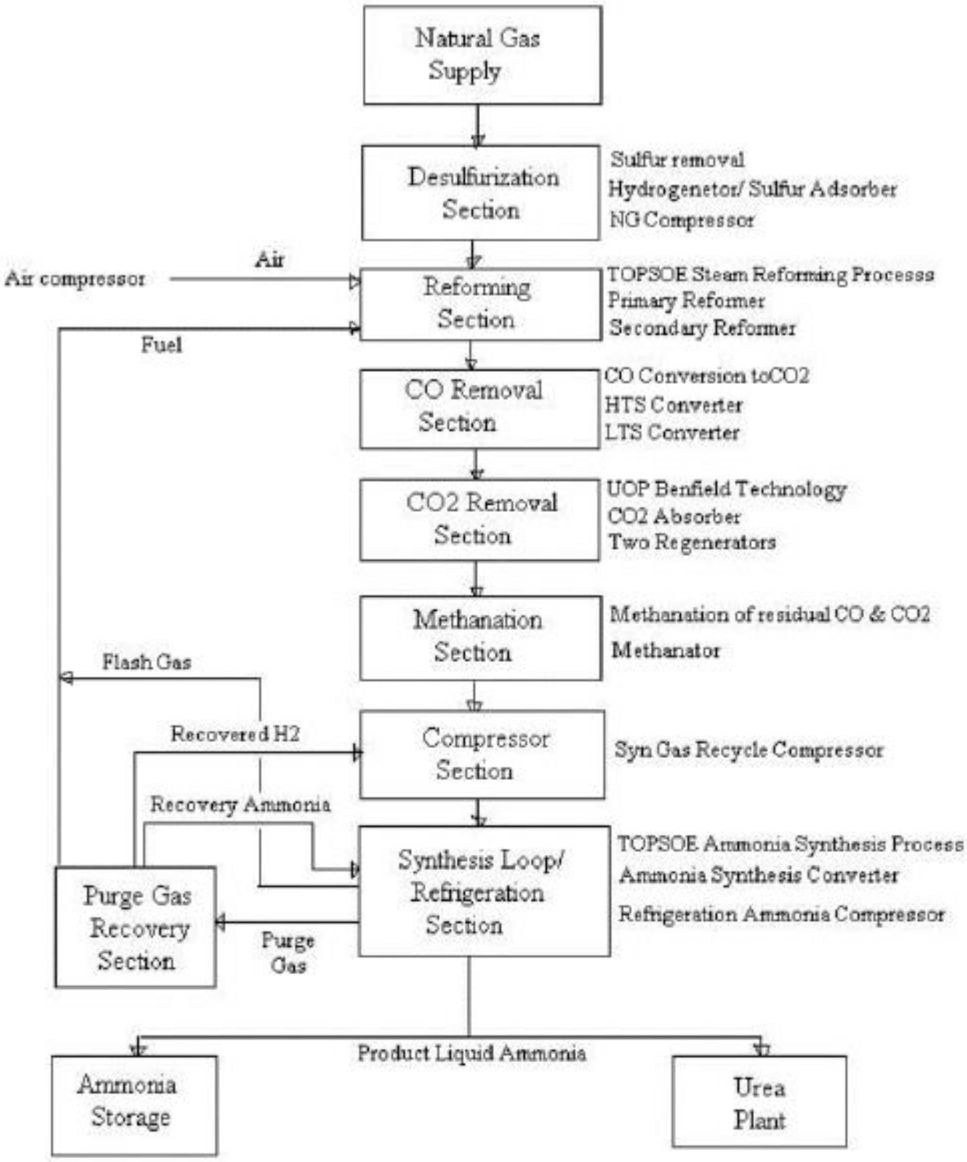


Figure 0.3: Block Diagram of Ammonia Plant

PNG PURIFICATION SECTION

Desulphurization vessel (DSV): The process natural gas is first purified to remove sulphur (S). If S is present, it may be condensed as sulfuric acid (H_2SO_4) which is hazardous for the process. At first organic sulphur is converted to inorganic hydrogen sulphide (H_2S) because zinc oxide (ZnO) is used to remove H_2S as zinc sulphide (ZnS) cannot absorb organic S.

The second purpose of purification section is to convert the unsaturated hydrocarbon to saturated hydrocarbon. For this purpose, Co-Mo catalyst is used. A natural gas compressor is used before the DSV to reduce the volume of gases and for effective adsorption of CO_2.

STEAM REFORMING

Primary reformer (PRF): Primary reformer has two sections: Furnace and Convection Zone. The block diagram of PRF is the following figure.

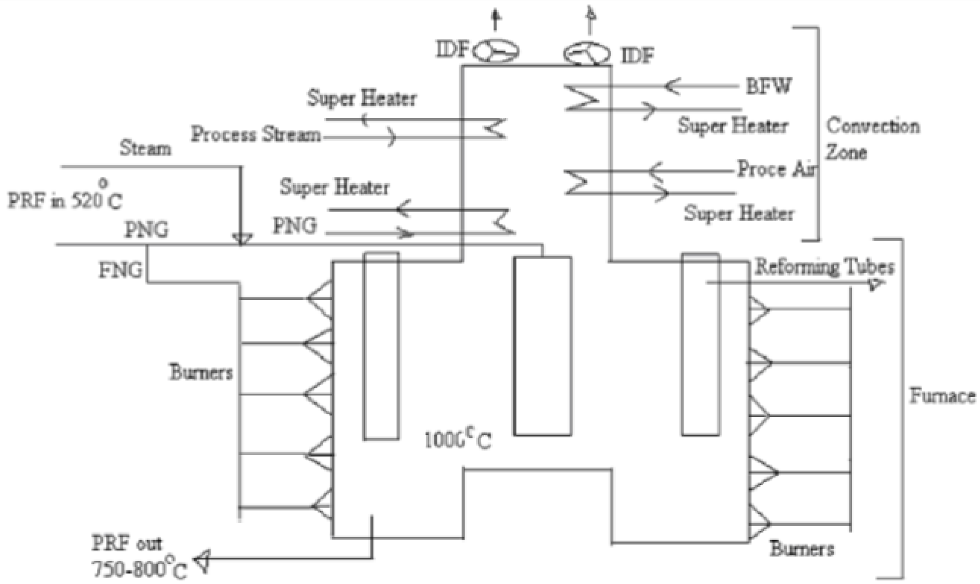


Figure 0.4: Block Diagram of Primary Reformer

- **Furnace:** The furnace zone is used to convert the unsaturated hydrocarbon mainly Methane (CH_4) to CO, CO_2 and H_2. For this purpose, Nickel (Ni) catalyst is used. This is an endothermic reaction. So, heat is required for quick reaction. In KAFCO, side firing is used in the furnace. A part of PNG is used as fuel in the furnace. Other part is used for steam reforming. Fuels are supplied using tubes. Tubes are designed to absorb certain temperature (T) and pressure (P). In primary reformer, vacuum is maintained. A logic system is used to maintain vacuum. The height of the furnace is 12 m. In the upper 3 m, there are pre-reformed catalysts. In the PRF, N_2 blanket is used to protect reduced catalyst from being oxidized.
- **Heat recovery in convection zone:** There is a convection zone in the upper part of the furnace. Huge heat energy is produced in the furnace section. Only 50-65% of the energy is used for reforming reaction. To recover the rest of the energy this convection zone is required. This energy is used for various purposes such as heating the process streams, process steam, process air, boiler feed water (BFW) etc. Around 35-40% energy can be recovered. Two induced draft fans (IDFs) are used to emit the exhausts of the PRF. The exhaust temperature is generally 185 ºC. The temperature of these gases should not be less than 100 ºC. If temperature is less than 100 ºC mist can form which can damage the IDF coil.

Secondary Reformer (SRF): In PRF, 100% conversion is not achieved. So, another reformer is used to convert the rest of the saturated hydrocarbon. Ni catalyst is also used in this section. Here, an additional reaction takes place. This additional reaction is combustion reaction of H_2 and O_2. This reaction is highly exothermic. Heat generated in this reaction is used in the re-forming reaction. There is a large space in the upper part of the secondary reformer where this highly explosive reaction takes place. In this section, process air is also injected.

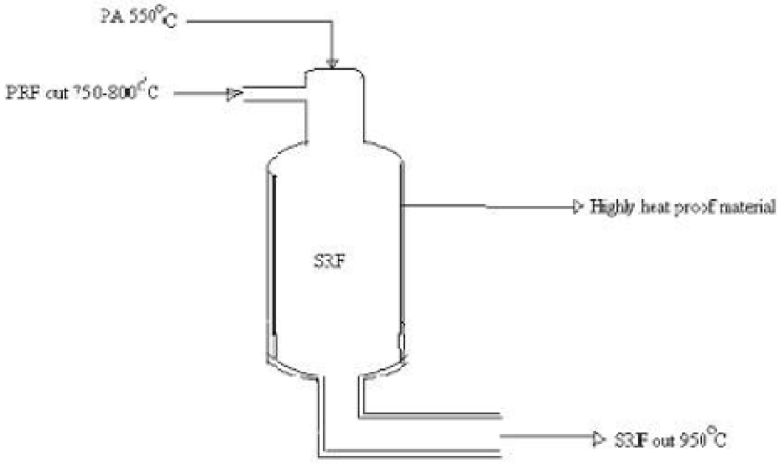


Figure 0.5: Block Diagram of Secondary Reformer

SHIFT CONVERSION

High Temperature Shift Converter (HTS): CO is undesired element for this process. CO is converted to CO_2 in this converter. The inlet and outlet temperature of this converter are respectively 360 ºC and 420 ºC. SRF out contains 30% CO and HTS out contains 3% CO. Fe_2O_3 is used as catalyst. The reaction in the HTS is exothermic reaction. At high temperature, rate of reaction increases and complete combustion is not achieved.

Low Temperature Shift Converter (LTS): This converter is used to convert the rest of the CO to CO_2. The outlet of the LTS contains around 0.3% CO. The outlet temperate is 230ºC. ZnO, Cr_2O_3/CuO are used as catalysts in this converter.

CO_2 REMOVAL

Benfield process: The objective of using this section is to get rid of the CO_2 obtained from the conversion of the CO in the shift converters since it is undesired in the next steps. In order to achieve this removal, Benfield process is carried out. Here hot potassium carbonate solution is used to absorb CO_2. Various additives are used with this solution to promote absorption and inhibit corrosion. The composition of this solution is 29% K_2CO_3, 2.9% DEA and 0.9% vanadium oxide (V_2O_5) with remaining water.

The CO_2 is absorbed chemically by the conversion of potassium carbonate to bicarbonate. As the solution pressure is reduced to about atmospheric pressure part of the CO_2 and water vapor escape. So an absorber and a regenerator are operated at 28 kg and 1 kg pressure respectively.

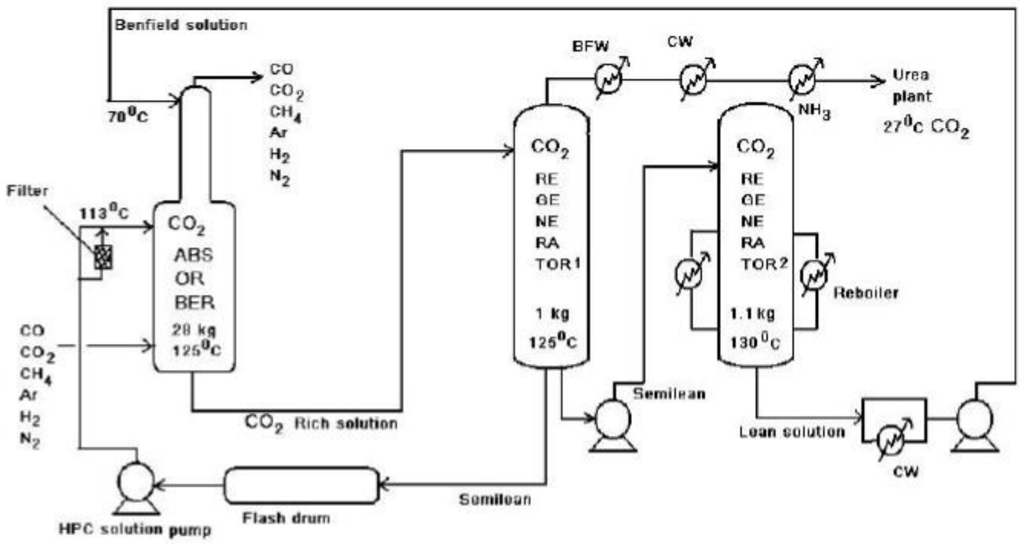


Figure 0.6: Block Diagram of CO_2 Removal Section

Here reboilers are used for better regeneration. Reboilers always supply latent heat and the solution is preheated so it is such named. The regenerator is operated at high temperature and the 113 ºC hot potassium carbamate solution enters into the absorber through a flash drum and this solution is semi lean. The temperature is maintained so that an optimum absorption is maintained. A side stream filter is used before the solution is entering the absorber since some dirt is present in the solution which must be scrubbed. A split ratio is maintained at about 3.5 which mean that the flow rate of the solution entering the absorber at the lower level than that of another solution entering the upper portion is about 3.5 times. The removed CO_2 is cooled by some cooling steps to get the cooled CO_2 which is very important to produce more urea.

METHANATION

After the removal of the CO_2 the remaining CO and CO_2 are converted to methane in this section. Methanator is used to ensure the removal of CO_2 and CO. In the methanator, a packing of catalyst is used. Here operation at lower temperature is advantageous due to thermal degradation at high temperature. In the methanator, 75% of the feed is converted. So, recirculation is used for reuse. In the methanator, nozzles are used as distributor so that no channelling occurs and the full conversion is occurred. Pressure safety valve (PSV) is used to keep the vessel safe and to operate at other than design value.

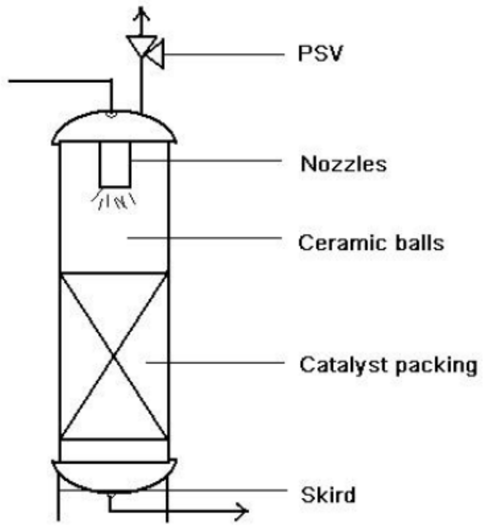


Figure 0.7: Simplified Diagram of Methanator

AMMONIA SYNTHESIS

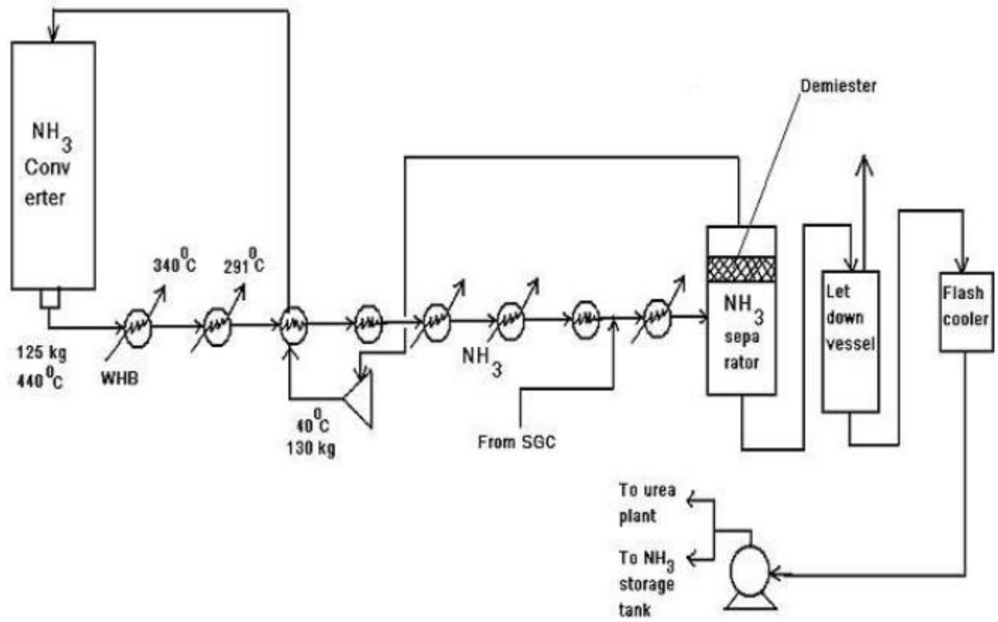


Figure 0.8: Simplified Diagram of KAFCO NH_3 Synthesis and Refrigeration Loop

The methanator outlet is cooled to 42 ºC before compressor since the volume will be less if a low temperature stream is compressed. As a result, power consumption will be lower. The gas is compressed to 130 kg and send to the ammonia converter. In the converter, hydrogen and nitrogen react in presence of iron (Fe) catalyst and are converted to ammonia.

NH_3 AND H_2 RECOVERY UNITS

Ammonia recovery: Ammonia is absorbed in the absorber at high pressure and low temperature. The absorbing agent is water. Water is regenerated at low pressure and high temperature in the regenerator and recycled back to the absorber. Ammonia and a trace amount of water are cooled in the condenser where water is condensed and separated from ammonia. About 99% pure ammonia is found by this process. Reflux is done for better purification and also to avoid thermal degradation.

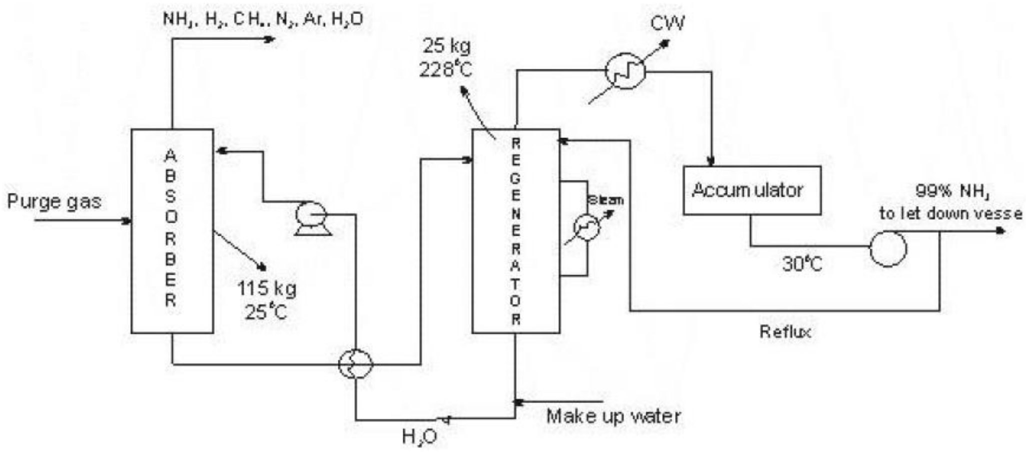


Figure 0.9: Simplified Diagram of NH_3 Recovery Unit

Hydrogen recovery: In KAFCO, there are two absorbers to absorb the little amount of ammonia and water as they may block the path because of ice formation at lower temperatures. One absorber remains in service and another one is in regeneration. After six hours of operation one absorber may be exhausted and need regeneration. Regeneration is done by recycled nitrogen. There are three heat exchangers inside a large vessel which is called a cold box. Start-up temperature of the cold box is the ambient temperature. There are 13 valves, through which the stream passes. Because of sudden expansion after passing the throttle valves, a mixture of liquid and vapor is formed.

Temperature goes down as it uses its internal energy to expand. This is called Joule-Thomson effect. The rate of temperature reduction is maintained at 10/15 ºC per hour to avoid thermal shock. About 10/12 hours are required to achieve a temperature of -187 ºC. At this temperature, nitrogen becomes liquefied, and gaseous hydrogen is separated and comes out from the top of the vessel.

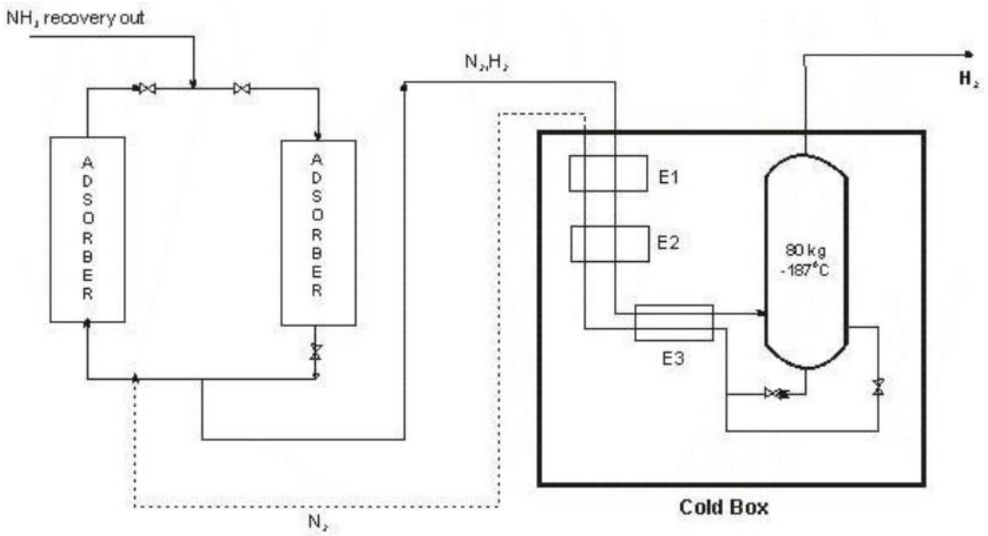


Figure 0.10: Simplified Diagram of H_2 Recovery Unit

AMMONIA STORAGE AT ATMOSPHERIC PRESSURE

A vessel can't be perfectly insulated. As a result, some molecules of ammonia become gas and eventually increase the vessel's pressure. Some ammonia may condense at high pressure and create a vacuum inside the storage tank. Ultimately, the vessel may squeeze and an undesired situation may occur. In KAFCO, ammonia is stored in a vessel of 20,000-ton capacity, and pressure is maintained at atmospheric pressure using a Boil of Gas (BOG) compressor. There are two BOG compressors in KAFCO. One is running and another one is on standby. A compressor compresses the gas and then gives up latent heat by exchanging it with cooling water. Thus, pressure is reduced and nearly atmospheric pressure is maintained in the storage tank. There is an accumulator which acts as a damping device and vents inert (mostly nitrogen) to the atmosphere. Otherwise, it will increase the partial pressure.

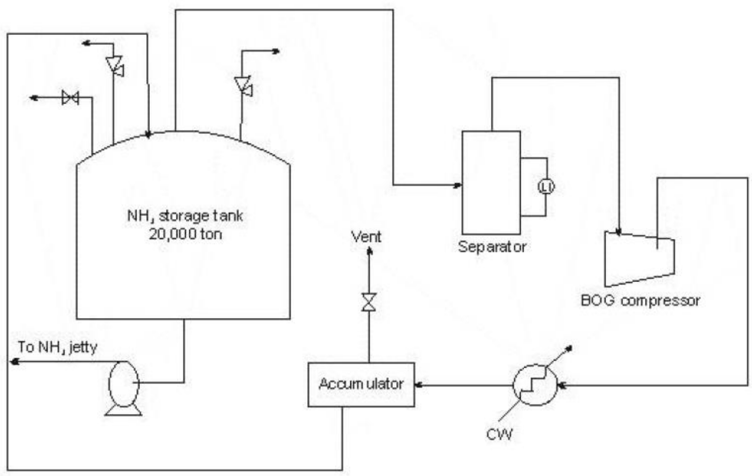


Figure 0.11: Block Diagram of NH_3 Storage at Atmospheric Pressure

1.6.2 UREA PRODUCTION PROCESS

The raw materials for urea production are NH_3, CO_2, and Formaldehyde (HCHO). There are the following sections in the urea plant.

- Compression section
- Synthesis section
- Purification/Decomposition section
- Recovery section
- Evaporation section
- Granulation section

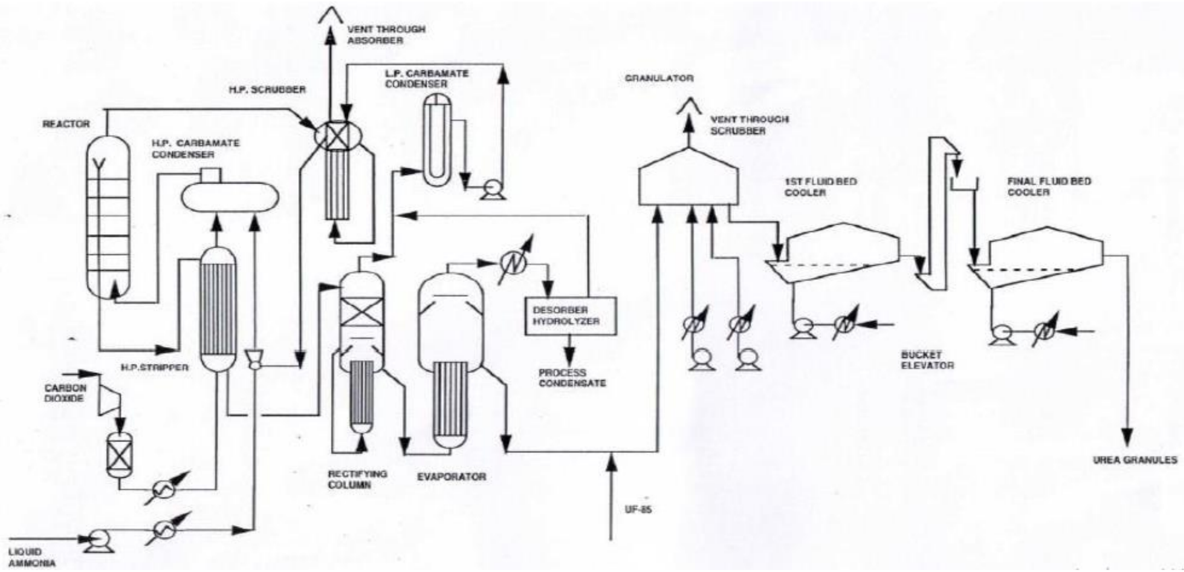


Figure 0.12: Process Flow Diagram of Urea Plant

COMPRESSION SECTION

CO_2 from the NH_3 plant is used. This CO_2 is not pure. It contains 99% CO_2, H_2 0.8% and N_2 0.2%. Impure CO_2 is mixed with air and sent to the compressor where the pressure develops from 12 kg to 152 kg. This is a 4-stage compressor with intercooler and separator in every stage. The intercooler reduces the temperature and the separator for moisture removal. Extraction admission condensing turbine is used to drive the compressor. H_2 converter is used to convert H_2 into water. The following reaction takes place.

$$H_2 + O_2 = H_2O$$

Pt catalyst is used. Excess air is also introduced for safety of equipment.

SYNTHESIS SECTION

There are 3 parts in the synthesis section.

Reactor: The reactor contains sieve trays. The liquid (urea solution) is introduced at the bottom of the reactor which moves upward through trays. After reaching a particular level it flows through a funnel again in the downward direction to the stripper. Normal carbon cannot be used as the construction material as urea solution is corrosive. The process body consists of three layers. Inner layer is made of sufforex, the middle part is of high-grade steel, and the outer layer is of carbon steel.

High pressure carbamate condenser (HPCC): For the first time, horizontal condenser is introduced in spite of a vertical one, which is termed as pool condenser. It is a shell and tube heat exchanger. Liquid is in the shell side whereas water in the tube side.

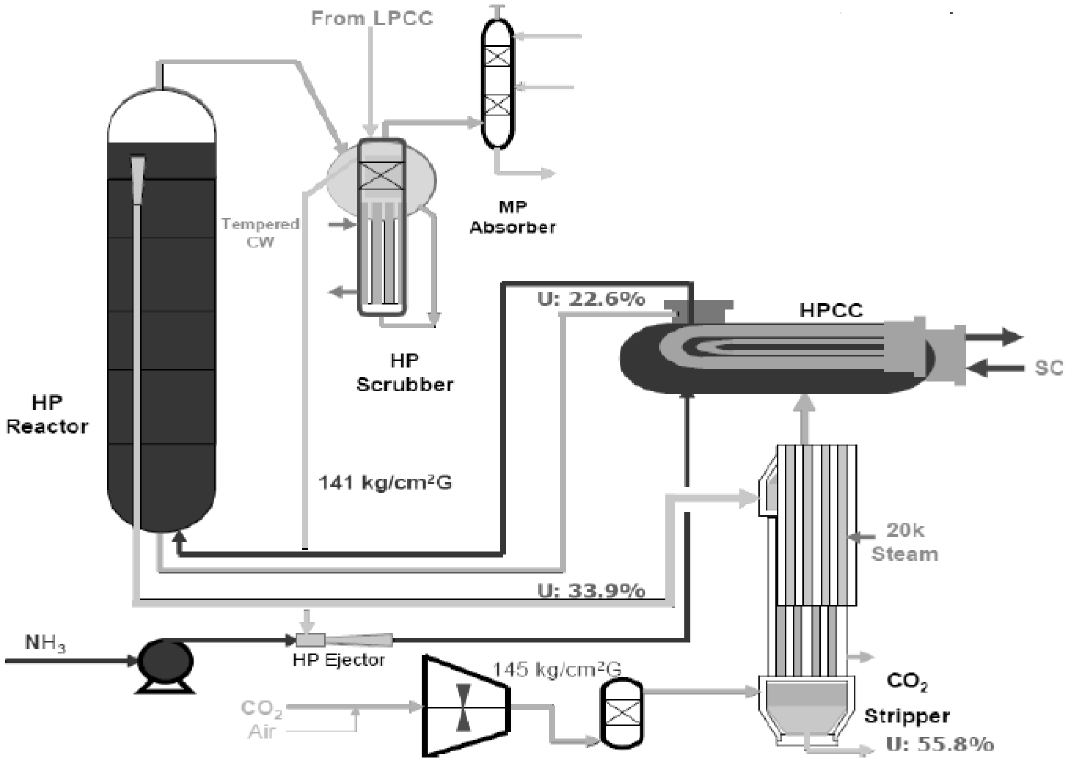


Figure 0.13: Process Flow Diagram of Synthesis Loop

Stripper: Here carbamate is stripped off using CO_2. CO_2 gas received from the ammonia plant is compressed to 145 kg/cm^{2}G pressure and charged to the high-pressure (HP) CO_2 stripper. Ammonia received from the ammonia plant is pumped to the high-pressure carbamate condenser at 162 kg/cm^{2}G, and part of the ammonia is also supplied to the low-pressure (LP) carbamate condenser. The recycle solution is mostly ammonia, CO_2 in water received through rectification and low-pressure carbamate condenser enriched with ammonia from low-pressure recovery section is also pumped to HP carbamate condenser through HP scrubber. Most of the reaction between CO_2 and NH_3 is performed in high pressure carbamate condenser where low-pressure steam is produced by utilizing the heat of reactions.

The solution from HP carbamate condenser is passed to urea rector and then to stripper. After the stripper, the pressure is reduced where upon almost all the carbamate is converted to urea and CO_2, ammonia in the gas phase is passed to LP carbamate condenser. The major part of non-converted NH_3 and CO_2 in the urea solution from the reactor is stripped off in the HP stripper. The gas phase from HP stripper is led to HP carbamate condenser, the liquid phase to the recirculation.

RECIRCULATION STAGE

In the recirculation stage, the major part of the remaining non-converted NH_3 and CO_2 are removed from the urea solution in the recirculation heater and led via rectifying column to the LP carbamate condenser. From the level tank for LP carbamate condenser the carbamate solution is recycled to the HP scrubber by means of the HP carbamate pump. At the outlet of this section urea is concentrated to 68%.

EVAPORATION SECTION

The urea solution from the rectifying column is discharged to the urea storage tank via the atm. flash separator. About 80% urea solution from the urea storage tank is concentrated to about 96% in one evaporation stage. There is a pre-evaporator (P = -0.55 kg). An ejector is used to create the vacuum. 96% urea melt from the evaporation is processed into a solid final product in the granulation section.

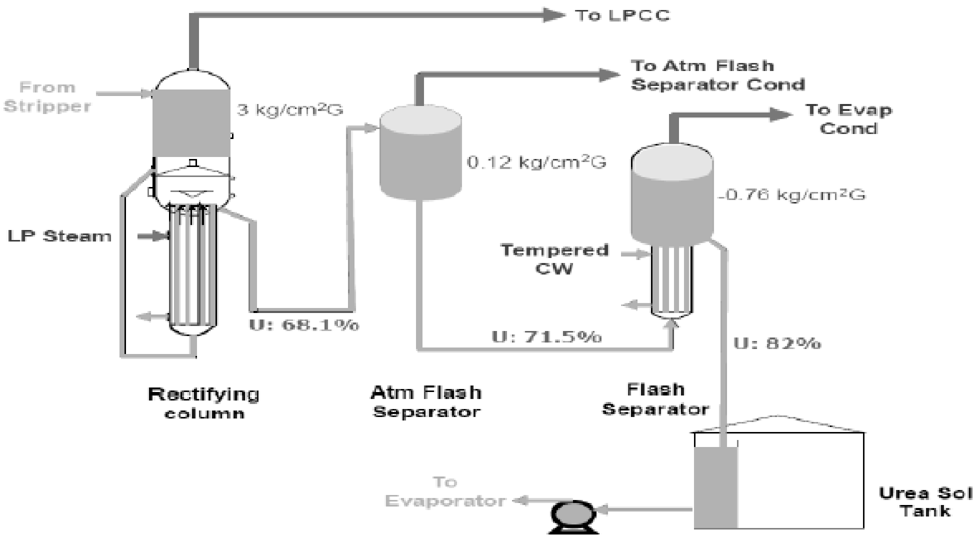


Figure 0.14: Process Flow Diagram of Urea Evaporation Section

GRANULATION UNIT

The urea solution at 96% concentration is delivered to the granulation unit battery limits at a pressure of about 7 kg/cm^{2}G and a temperature of 132 - 135 °C. The feed solution is sprayed via nozzles. In the unit, there are 198 nozzles within 9 headers. The whole unit has been divided into 6 chambers. Three of these are termed as cooling chambers. The headers are equally distributed among the other three chambers.

UF 85 (in the form of urea/formaldehyde pre-condensate) is metered into the urea feed solution as a process aid and anti-caking agent. The formaldehyde containing urea solution, at 96% concentration, is dispensed to the injection heads and sprayed by atomization air, compressed by the atomization air blower on the fluidized bed granulator. Atomized air is heated with steam before injection to avoid solidification of urea at the nozzle. In this process, particle size grows by continuous evaporation and solidification of a large number of minute drops of the solution into the initial particle called the seed or nucleus (accretion process). The granulated product from the granulator is down in the first fluid bed cooler and thereafter is taken up to the screening section by the bucket elevator.

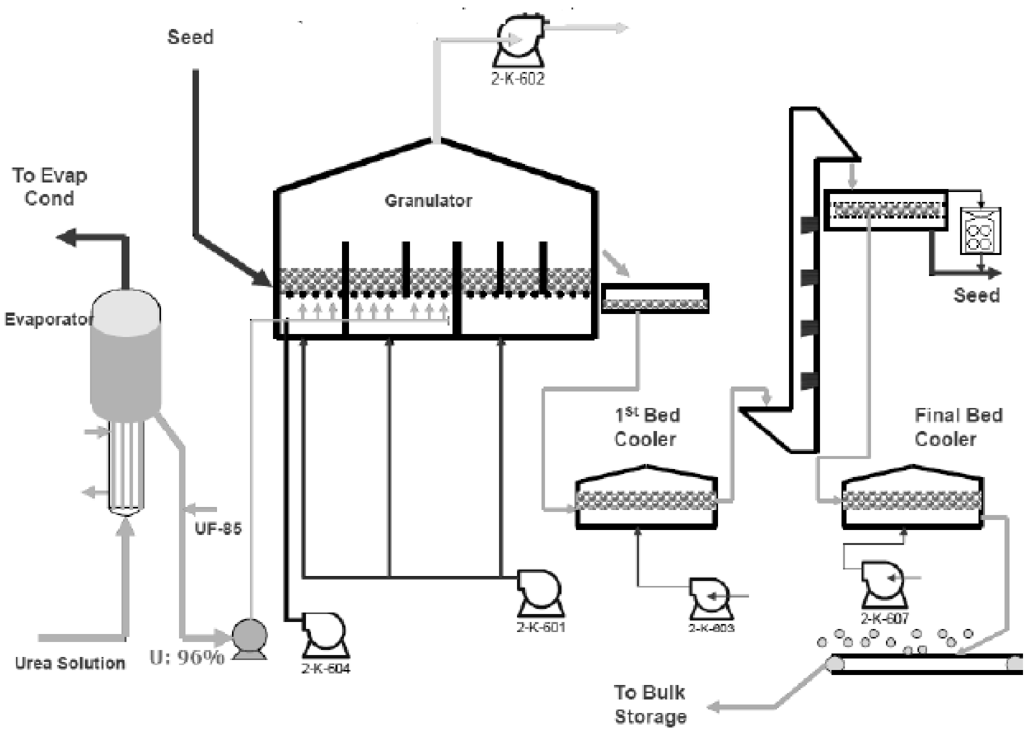


Figure 0.15: Process Flow Diagram of Granulation Unit

In the screening section, urea granules are separated into three fractions; on-size (2-4 mm, end product), undersize (below 2 mm, fine), and oversize (coarse). Undersize fraction is recycled directly and oversize fraction is recycled after crushing into the granulator and used as a seed or nucleus.

PRODUCT HANDLING AND STORAGE SECTION

Product handling and storage section is responsible to maintain the stock of urea by controlling the product quality within the specified condition and dispatch the materials for abroad and domestic purpose. The bulk product is distributed and piled up in the bulk storage area by the storage stripper car. The maximum height and distance of the pile are 16500 mm and 700 mm respectively. Unit fan heaters are used for heating the inside air of bulk storage for dehumidification. The following figure shows the flow chart of urea storage and distribution section.

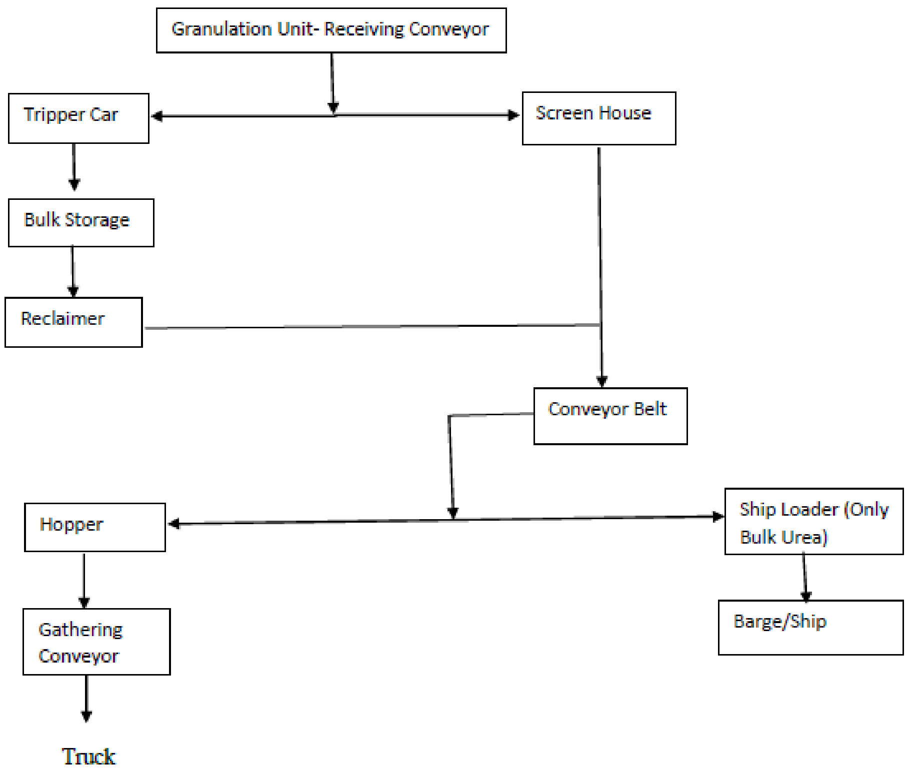


Figure 0.16: Flow Chart of Urea Storage and Distribution Section

1.6.3 THE UTILITY SYSTEM

The utility plants in KAFCO are as follows:

1. Utility steam generation and distribution process
2. Fire-water and cooling water system
3. Boiler feed water production and distribution process (Demineralization unit)
4. Nitrogen generation process and distribution
5. NG and water intake, treatment, and distribution process
6. Effluent treatment plant (ETP)
7. Plant air and instrument air systems

UTILITY STEAM GENERATION AND DISTRIBUTION PROCESS

Steam Generation

Source: BFW, NG, combustion air, chemicals (hydrous ammonia N2H4, PO4 solution).

Main Equipment: 2 natural circulation pressurized vertical water tube boiler (package boiler), 1 BFW pump, 2 forced draft (FD) fans for the boiler 1 is turbine driven and 1 is motor driven.

Uses: Steam generation at 95 TPH/boiler and distribution to mainly 2 STGs.

Main Features: KAFCO has two natural circulations natural gas-fired package boilers made by MACCHI, Italy. The boiler furnaces operate under positive pressure and in completely water-cooled conditions of furnace floors, walls, and roofs consisting of membrane wall construction. The furnace is completely enclosed by water walls. The space between the tubes is closed by the fins which overlap each other. Thereby forming a completely gas-tight seal enclosure.

The water walls are the rear wall, intermediate wall, and front wall. There are D-tubes forming the floor, side, and roof walls. These tubes are continuous construction entering directly into the steam and water drums. Suitable excess doors are provided on the front wall, intermediate wall, and side wall in order to inspect the furnace, super-heater, and boiler bank tubes during boiler overhaul. The boiler is fired under positive pressure and products of combustion travel the full length of the furnace before entering the superheater located within the furnace. One economizer is arranged on one side of the boiler.

Table 0.4: Boiler Parts with their Description

No.	Name	Description
1	Boiler Production	High-pressure (HP) steam to header, Design Capacity 95 ton/hour at 510 ^oC
2	Superheater	BFW added to maintain the HP steam temperature at 510 ^oC
3	Boiler Feed Water (BFW)	BFW, Design Feed: 95.95 ton/hr to steam drum at 140 ^oC gaining temperature through economizer up to 190 ^oC
4	Chemical Dodging	Phosphate solution to create a passive layer inside the steam drum
5	Continuous Blow Down (CBD)	Keep impurities such as silica concentration constant in the loop
6	Natural Gas (NG)	Design fuel inlet flow rate 7.82 kNm^3/hour as a source of heat energy
7	Forced Draft Fan	• Supply combustion air at 80 T/hr • Motor and steam-driven
8	Superheater	Increase saturated steam temperature from 323 ^oC to 510 ^oC

Steam Distribution System

Steam in KAFCO plant has five different pressure levels which are used in utility, ammonia and urea plants. In utility and urea plant, the three different pressure levels are as follows:

High Pressure (HP) Steam:

- ✓ Pressure: 109 kg
- ✓ Temperature: 510 ^oC
- ✓ Design pressure/temperature: 122 kg, 548 ^oC

Medium Pressure (MP) Steam:

- ✓ Pressure: 38.1 kg
- ✓ Temperature: 380 ^oC
- ✓ Design pressure/temperature: 46 kg, 410 ^oC

Low Pressure (LP) Steam:

- ✓ Pressure: 4.2 kg
- ✓ Temperature: 220 ^oC
- ✓ Design pressure/temperature: 7 kg, 260 ^oC

Besides, in the Urea plant,

- ✓ 20 kg steam is used in the stripper & hydrolyser
- ✓ 8 kg steam is used for heating purposes in the granulation unit, ejector, steam jacketing, and tracing

FIRE-WATER AND COOLING WATER SYSTEM

FIRE WATER SYSTEM

Source: Filtered water

Main Equipment: Jockey pump, Motor-driven pump, Diesel-driven pump

Uses: As fire protection water

Function:

- Jockey pump to maintain the fire water header pressure
- Normally for any use of fire water, the motor-driven pump starts automatically by a low-pressure switch.
- In case of start-up failure of the motor-driven pump or further increase of fire water demand, the diesel-driven pump starts automatically by a low-pressure switch.

COOLING WATER SYSTEM

Source: Filtered water (as makeup water)

Main Equipment:

- ✓ 10 induced draft fans (IDFs)
- ✓ 3 main cooling water pumps
- ✓ 2 priority cooling water pumps
- ✓ 2 side stream filters
- ✓ chemical injection unit

Use: Cooling the total return cooling water maintaining the desired quality

BOILER FEED WATER PRODUCTION AND DISTRIBUTION PROCESS (DEMINERALIZATION UNIT)

Source: Filtered water, process condensate, steam condensate.

Main Equipment: 3 activated carbon filters, 3 cation exchangers, degasifier, 2 degasifier fans, 2 pumps, 3 anion exchangers, 3 polisher feed pumps, 3 mixed bed polishers, chemical injection unit, neutralization unit.

Use: Boiler feed water 400 TPH

Main features: Dissolved ions are removed in the demineralization unit. Different types of resin are used according to necessity.

Mixed bed polisher: It is used to obtain the highest purities in the treatment of feed water and condensate for high-pressure steam boilers. Both cation and anionic resins are used in the polisher.

NITROGEN GENERATION PROCESS AND DISTRIBUTION

- ✓ The N_2 plant is designed to produce both LP and HP N_2 which are produced by cryo-genic distillation process.
- ✓ N_2 is used in different units of the process plant for auxiliary, purging drums, vessels, piping, etc., before or after its maintenance and before start-up.
- ✓ N_2 is used in various equipment/reactors to maintain an inert atmosphere during the process plant shut-down (S/D) state. N_2 is useful, especially for catalytic reactors.
- ✓ Low-pressure (LP) and high-pressure (HP) N_2 are used in the ammonia plant during the plant's start-up.

- ✓ Liquid N_2 is stored in a liquid N_2 storage tank to supply the higher LP N_2 demand and HP N_2 demand of the ammonia plant during the plant's start-up.
- ✓ Plant air is fed to the N_2 generation unit, where moisture and any other impurities are separated before introducing it to a cold box for N_2 production. Silica gel and molecular sieve are used in the absorber to remove H_2O and CO_2 respectively.
- ✓ LP N_2 is being used intermittently in the utility stations located in the plant's different areas.

Main Components of the N_2 Plant: Refrigeration unit**,** Adsorption unit**,** Cryogenic unit**,** and Storage unit

Main Components of the Refrigeration Unit:

- ✓ Two refrigeration compressors
- ✓ Refrigeration condenser
- ✓ Refrigeration evaporator/air cooler

Main Components of the Absorption Unit:

- ✓ Two absorber
- ✓ Refrigeration heater

Main Components of the Cryogenic Unit:

- ✓ Distillation column
- ✓ Reflux condenser
- ✓ Main heat exchanger
- ✓ Gas-bearing expansion turbine

Main Components of the Storage Unit:

- ✓ Storage tank
- ✓ Vaporizer

NG AND WATER INTAKE, TREATMENT, AND DISTRIBUTION PROCESS

Natural Gas Intake and Distribution System

Source: Karnaphuli Gas Distribution Company Limited (KGDCL)

Main Equipment:

- ✓ 1 NG KOD (NG Knock-Out Drum)
- ✓ 2 KGDCL inlet lines with filter
- ✓ 3 KGDCL supply lines with pressure regulator

Uses: Separating NG condensate and distributing NG to the user side

Features:

- ✓ NG is supplied by KGDCL.
- ✓ NG is being received through the NG knock-out drum and distributed to the packaged boilers, ammonia plant, 4 MW dual fuel engine generator, and flare stack.
- ✓ Flow, pressure, and temperature of NG are recorded through instruments, while NG composition is analyzed in the laboratory.
- ✓ There is a provision to supply canteen NG directly from the plant side after reducing the pressure by a pressure-reducing valve (PRV).

Source: Raw Water Intake and Treatment System

Raw Water Intake System

Source: Groundwater

Main Equipment: 10 deep well pumps. However, 6 to 8 pumps operate simultaneously. others remain as standby, for redundancy.

Pump Type: Vertical, submerged, and centrifugal

Pump Capacity: 80 to 160 m^3/h

Use: As input to clarifier

Supply: 625 m^3/h

Raw Water Treatment System

Source: Raw water

Main Equipment:

- ✓ 2 clarifiers
- ✓ 8 sand filters

Use: As the makeup for the cooling tower, demineralized water, service water, potable water, and fire water

EFFLUENT TREATMENT PLANT (ETP)

Chemical drain/ rain water from equipment in the utility and other areas and wastewater from the laboratory is collected in no. 3 drain pit through underground piping. Then, the wastewater is transferred by no. 3 drain pump to the neutralization pit or the open ditch sewer depending on the pH of the wastewater which is monitored by the pH analyzer.

Wastewater discharge at upset condition of the urea plant may be too bad to be treated in the neutralization facilities. A hose connection is provided at the discharge of the no. 2 drain pit to pack the wastewater in a drum container for such conditions.

Normally, the wastewater in no. 3 drain pit is discharged to the open ditch sewer since the pH of the wastewater is expected within 6.5-8.0. However, when pH becomes out of the range, the wastewater in no. 3 drain pit shall be transferred to the neutralization pit by opening the valve manually.

The pump is started/stopped automatically by the high/low water level signal from the pit. Treated wastewater from the neutralization pit is discharged to the open ditch sewer through underground piping. Each treated sanitary wastewater in sanitary treating packages of the wastewater system is discharged to the open ditch sewer through underground piping.

PLANT AIR AND INSTRUMET AIR SYSTEMS

Processed air is an inevitable element for the plant. In normal operation, compressed air is extracted from the process air compressor. The ammonia plant air is fed as plant air to the compressed air receiver.

This unit consists of plant air and instrument air and comprises of basically two air compressors and dryers. Air is compressed by air compressors and supplied to the plant air header and again part of this air is passed through a dryer unit for purification where all the moisture is absorbed and the dryer outlet air supplied to the instrument air header for the use of different instruments. The plant air and instrument air system shall be continuously operated to the plant air and instrument air even if the ammonia, urea, and other utility facilities are shut down.

Plant Air System

In normal operation, compressed air is extracted from downstream of the 3rd separator of the process air compressor in the ammonia unit and fed as plant air to the compressed air receiver via a pressure-indicating controller set at 10 kg/cm^2. Motor-driven air compressor packages supply plant air in case plant air from the process air compressor is not available or not sufficient.

Start-up of air compressors after prolonged shutdown shall always be carried out locally to ensure a safe and stable operation of the compressors. Both compressors must be checked for proper lube oil pressure, sufficient cooling water flow, load and unload operation by the local pressure switches, noises, vibration, etc. When the compressors are set for remote operation by the remote/local selector switches on the local control panels, the compressors are automatically started by the signals from the pressure switches which monitor the operating pressure of the compressed air receiver.

The selector switch is provided in the central control room (CCR) which gives priority to operating first either of the air compressors. In case of electrical power failure, both compressors are stopped. However, the power source of the compressors is automatically shifted to the emergency electrical power from the diesel engine generator. Both compressors will be ready for operation automatically after a short period.

Plant Air Demand:

- ✓ Intermittent use from the header: 500 Nm^3/hr per station
- ✓ Instrument air dryer: 1,250 Nm^3/hr
- ✓ Inert gas generation: 1,500 Nm^3/hr
- ✓ Used in boiler scanners: 160 Nm^3/hr

Instrument Air System

- ✓ A part of the plant air is stored in the compressed air receiver and is fed to the air dryer packages which reduces the air pressure and controls it at 8.3 kg/cm^2.
- ✓ Air dryer packages are of pressure swing heatless type and reduce the moisture content to -10 °C dew point at 7.0 kg/cm^2.
- ✓ The instrument air receiver stores dried air and supplies it to the users through the instrument air distribution header.
- ✓ The instrument air receiver can supply instrument air for about 8 minutes till the receiver pressure drops from 7.9 to 4.0 kg/cm^2.
- ✓ An automatic shutdown valve is installed on the plant air distribution header. When the instrument air pressure falls below the preset value of 6.8 kg/cm^2, this valve closes automatically, and all the plant air distribution stops except for the package boilers as cooling air for flame scanners.
- ✓ When the pressure drops further to 6.0 kg/cm^2, compressed air fed to the inert gas generator is cut off automatically.

Air Supply to Inert Gas Generator: Compressed air to the inert gas generator is supplied from the compressed air receiver which reduces the air pressure and controls it at 9.0 kg/cm^2.

Instrument Air Demand:

- ✓ Automatic unit: 420 Nm^3/hr
- ✓ Urea unit: 180 Nm^3/hr
- ✓ Utility station: 400 Nm^3/hr

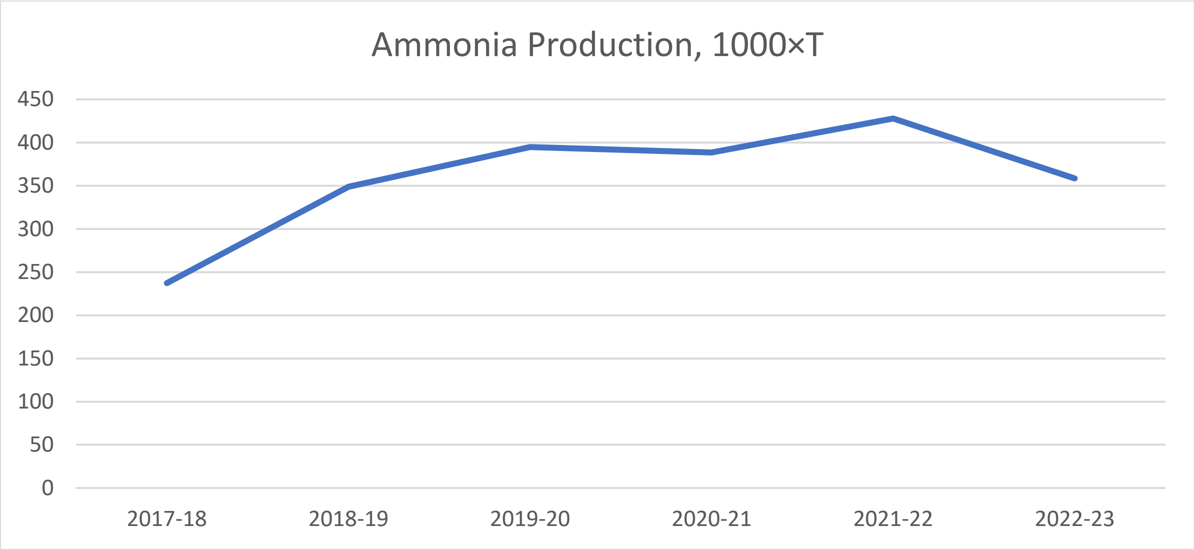
CHAPTER 2: PERFORMANCE ASSESSMENT

The KAFCO is a very energy intensive factory. The performance assessment of equipment of the fertilizer factory is crucial for ensuring the efficiency, reliability, and overall effectiveness of the production processes. KAFCO is using natural gas to produce ammonia, urea production and electricity generation. In the original design concept; 520 MT/day excess ammonia production was considered for export. However, over the years due to gas supply restrictions, excess ammonia production is reduced to a minimum level so as to optimized & balanced the ammonia-urea processes. The present amount of excess ammonia is produced automatically out of process optimization and from H_2 recovery from purge gas. The efficiency of the ammonia synthesis process and subsequent urea synthesis steps play a significant role in energy intensity. Improvements in reaction kinetics and heat recovery systems can contribute to reduced energy consumption. The cooling and condensation steps are critical in the urea production process. Effective heat exchange systems can contribute to energy efficiency by recovering and reusing heat, thereby reducing the overall energy input required. The efficiency of utility systems, such as boilers, compressors, cooling tower and so on, contributes to the energy intensity of the entire facility.

2.1 PERFORMANCE OF THE AMMONIA PLANT

Table 2.1.1: Performance of the Ammonia Plant

Financial Year	Ammonia Production, 1000×T	Specific Energy Consumption for Ammonia, GJ/T	Specific Energy Consumption for Ammonia, MSCF/T
2017-18	237.24	35.49	35.66
2018-19	348.84	33.67	33.82
2019-20	394.64	33.86	34.01
2020-21	388.46	33.68	33.83
2021-22	427.90	33.14	33.30
2022-23	358.36	33.77	33.93
Average	**359.24**	**33.93**	**34.09**



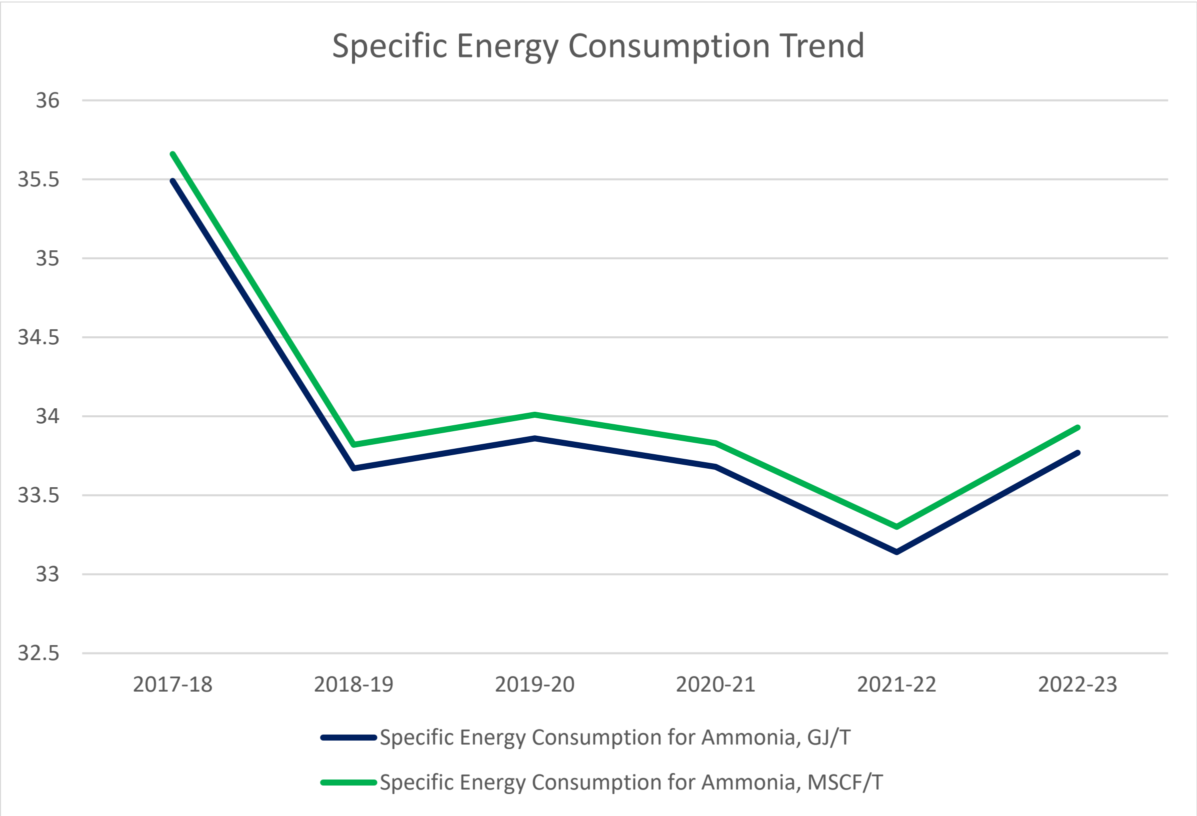
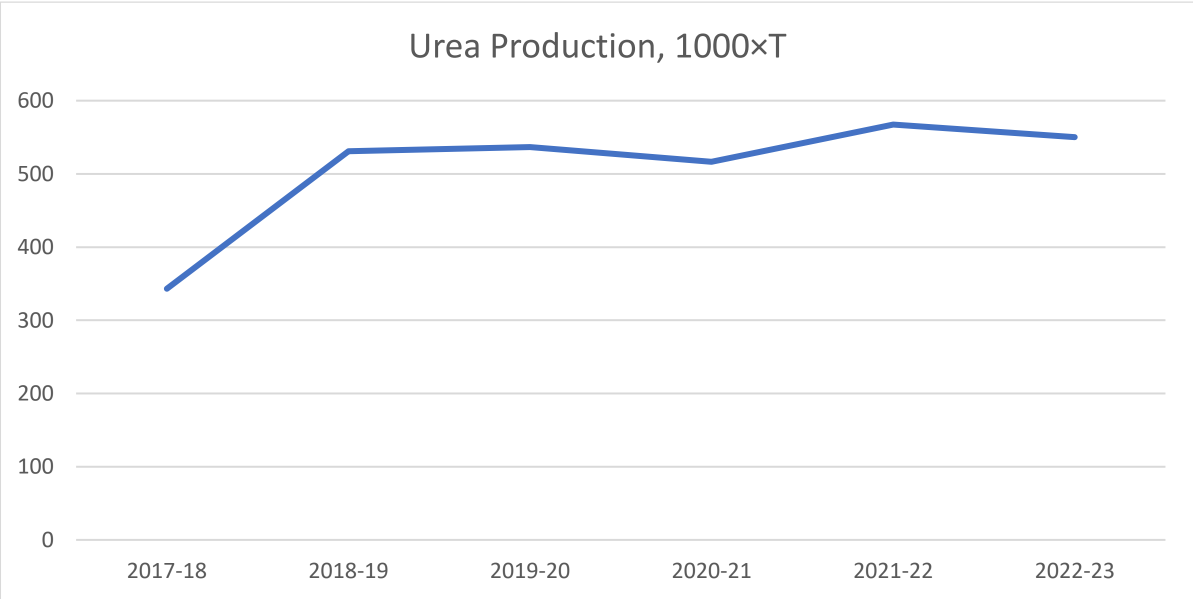


Figure 2.1.1: Ammonia Production and Specific Energy Consumption

2.2 PERFORMANCE OF THE UREA PLANT

Table 2.2.1: Performance of the Urea Plant

Financial Year	Urea Production, 1000×T	Specific Energy Consumption for Urea, GJ/T	Specific Energy Consumption for Urea, MSCF/T
2017-18	343.14	26.90	27.18
2018-19	531.06	24.22	24.47
2019-20	536.70	24.64	24.90
2020-21	516.62	24.96	25.22
2021-22	567.36	23.87	24.12
2022-23	550.22	24.30	24.55
Average	**507.52**	**24.82**	**25.07**



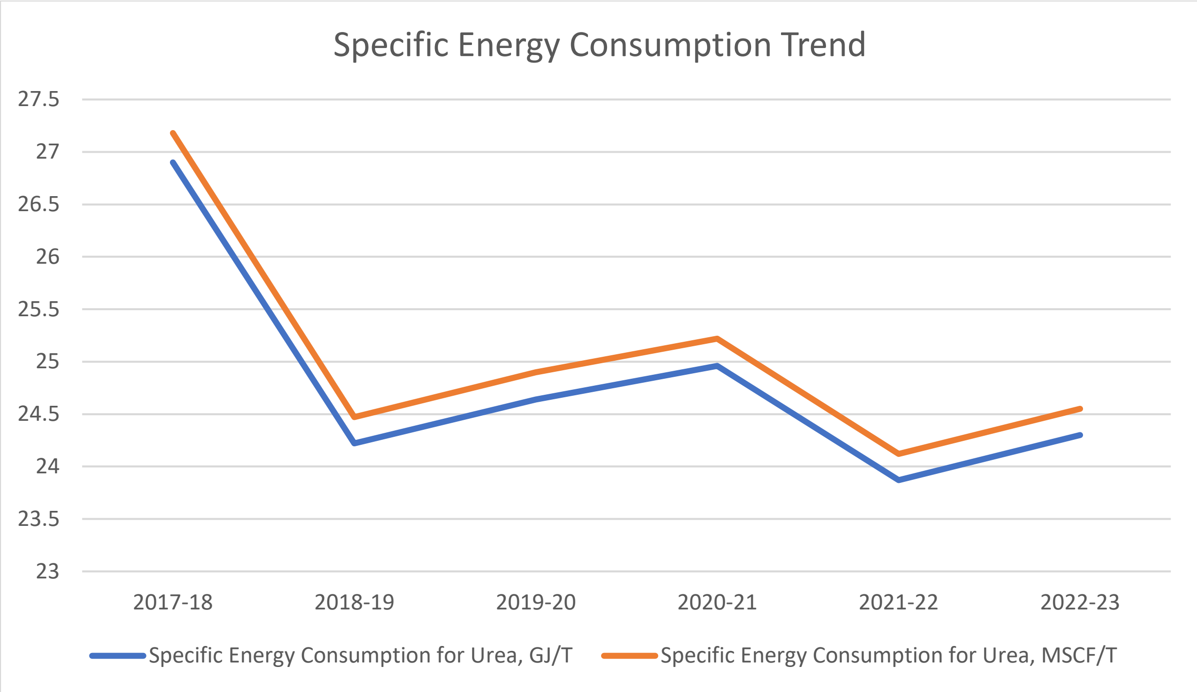


Figure 2.2.1: Urea Production and Specific Energy Consumption

2.3 SHARE OF GAS CONSUMPTION

Table 2.3.1: Historical Data Showing the Share of Gas Consumption

Financial Year	Production (PNG+ FNG to Reformer 1), MMSCF/year	Power & steam co-generation (Fuel to Aux. Boilers), MMSCF/year
2017/18	7,462	3,324
2018/19	10,625	3,912
2019-20	12,162	4,202
2020-21	11,838	4,349
2021-22	13,006	4,140
2022-23	10,937	4,069

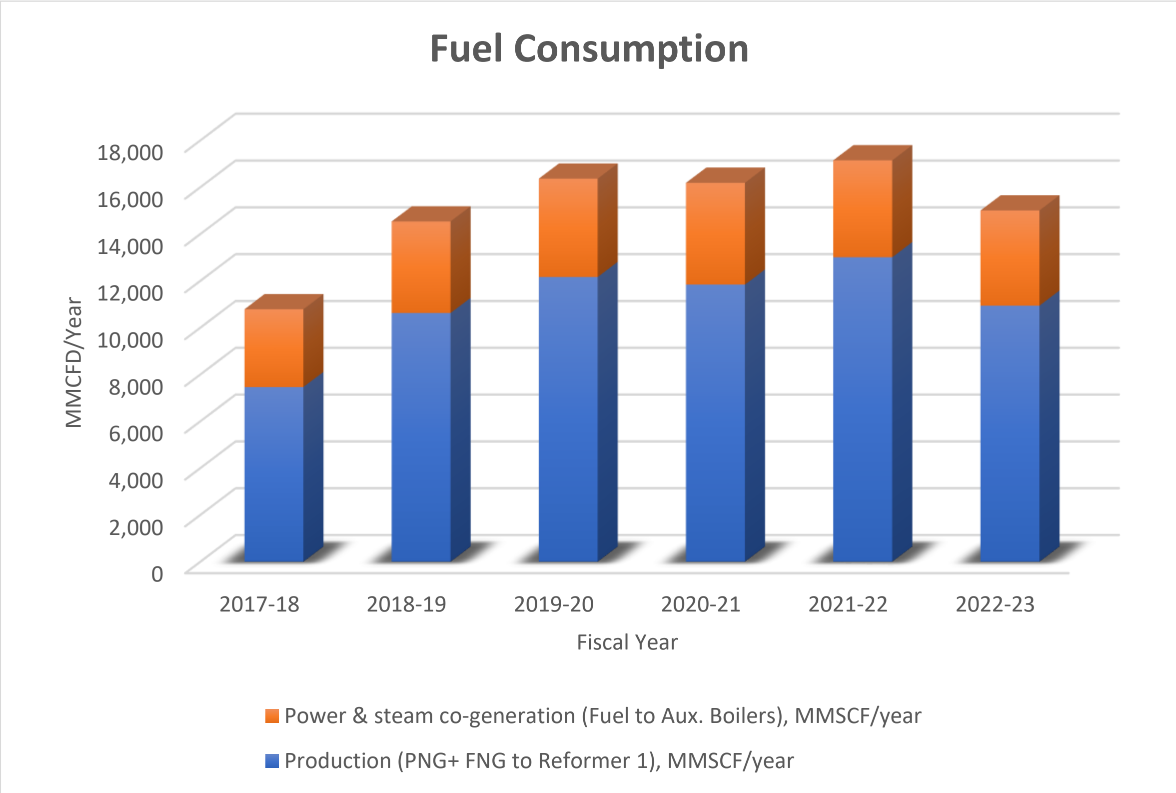


Figure 2.3.1: Historical Data Showing the Share of Gas Consumption

2.4 Share of Electricity Consumption

Table 2.4.1: Historical Data Showing the Share of Electricity Consumption

Financial Year	Production (Ammonia plant + Utility Plant), MWh/year	Production (Urea plant + Bagging), MWh/year	Office & non-production application (Sub-Stations D, E and Housing), MWh/year
2017-18	69,591.57	22,596.26	4,005
2018-19	72,161.30	31,704.90	4,317
2019-20	78,445.75	35,750.02	4,183
2020-21	78,353.21	37,035.22	4,511
2021-22	79,519.54	33,799.36	4,536
2022-23	73,498.39	33,188.16	4,599

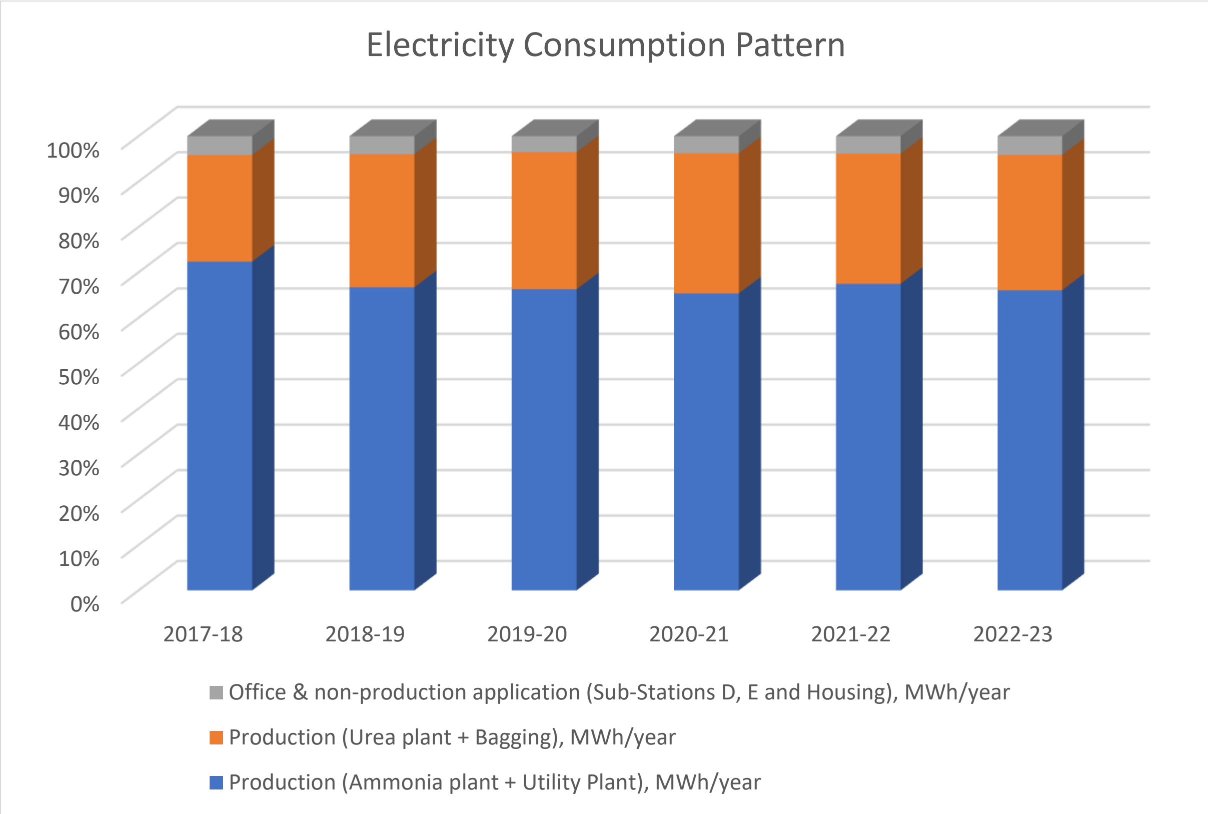


Figure 2.4.1: Historical Data Showing the Share of Electricity Consumption

2.5 Share of Steam Consumption

Table 2.5.1: Historical Data Showing the Share of Steam Consumption

Financial Year	CHP (STG-1 and STG-2): HP Steam (from Boiler-1 and 2) [109 kg/cm^{2}G and 513 ^{o}C], MT/year	Throttling (Let Down): HP Steam (from Boiler-1 and 2) [109 kg/cm^{2}G and 513 ^{o}C], MT/year	Production, MP Steam (from CHP, STG-1, and 2 and let-down) [38 kg/cm^{2}G & 380 ^{o}C], MT/year
2017-18	979,097.00	111,600.00	864,600
2018-19	1,146,597.00	154,811.00	1,111,572
2019-20	1,390,693.00	88,361.90	1,299,975
2020-21	1,456,162.00	76,339.00	1,360,878
2021-22	1,361,275.00	105,015.00	1,282,184
2022-23	1,277,192.00	107,808.00	1,205,984

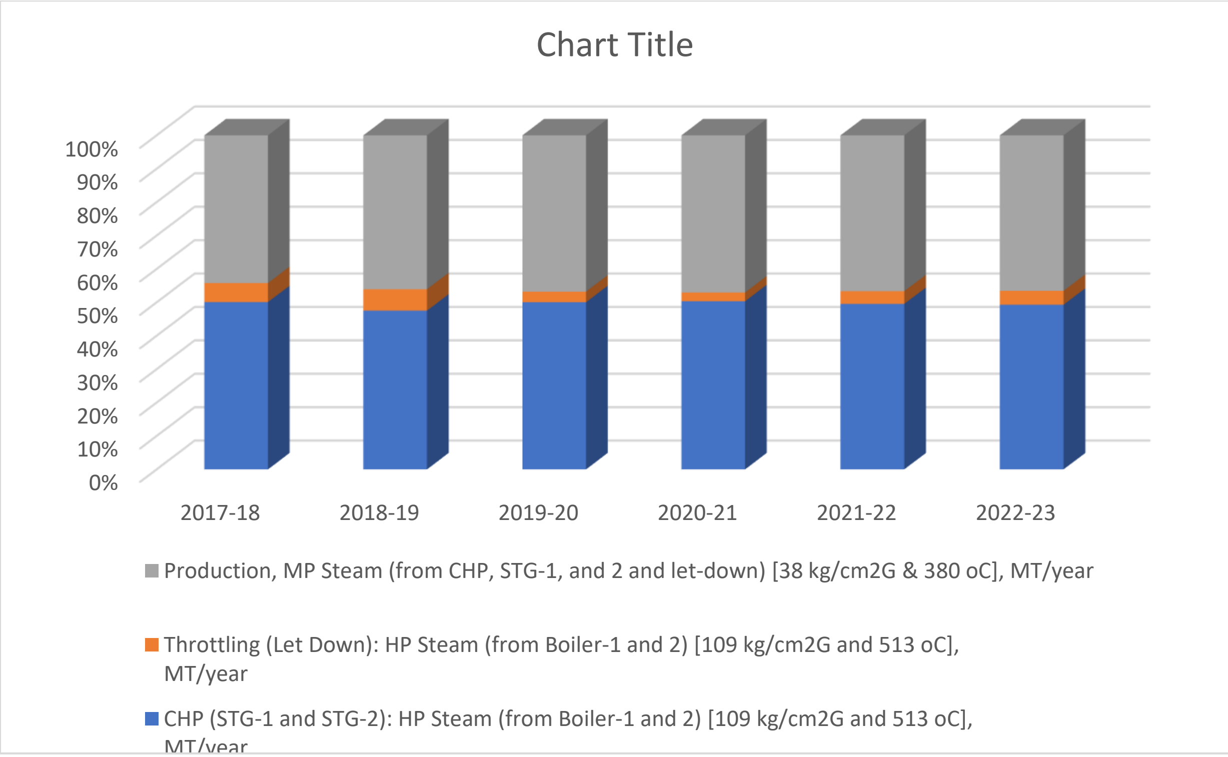


Figure 2.5.1: Share of Steam Consumption Over the Years

2.6 SHARE OF WATER CONSUMPTION

Table 2.6.1: Historical Data Showing the Share of Water Consumption

Financial Year	**Production, 1000 m^3/year**	**Steam Generation, 1000 m^3/year**	**Others, 1000 m^3/year**
2017-18	3,122.00	467.00	413
2018-19	4,108.00	478.00	418
2019-20	3,680.00	455.00	376
2020-21	4,000.00	499.00	432
2021-22	4,064.00	473.00	394
2022-23	4,180.00	460.00	387

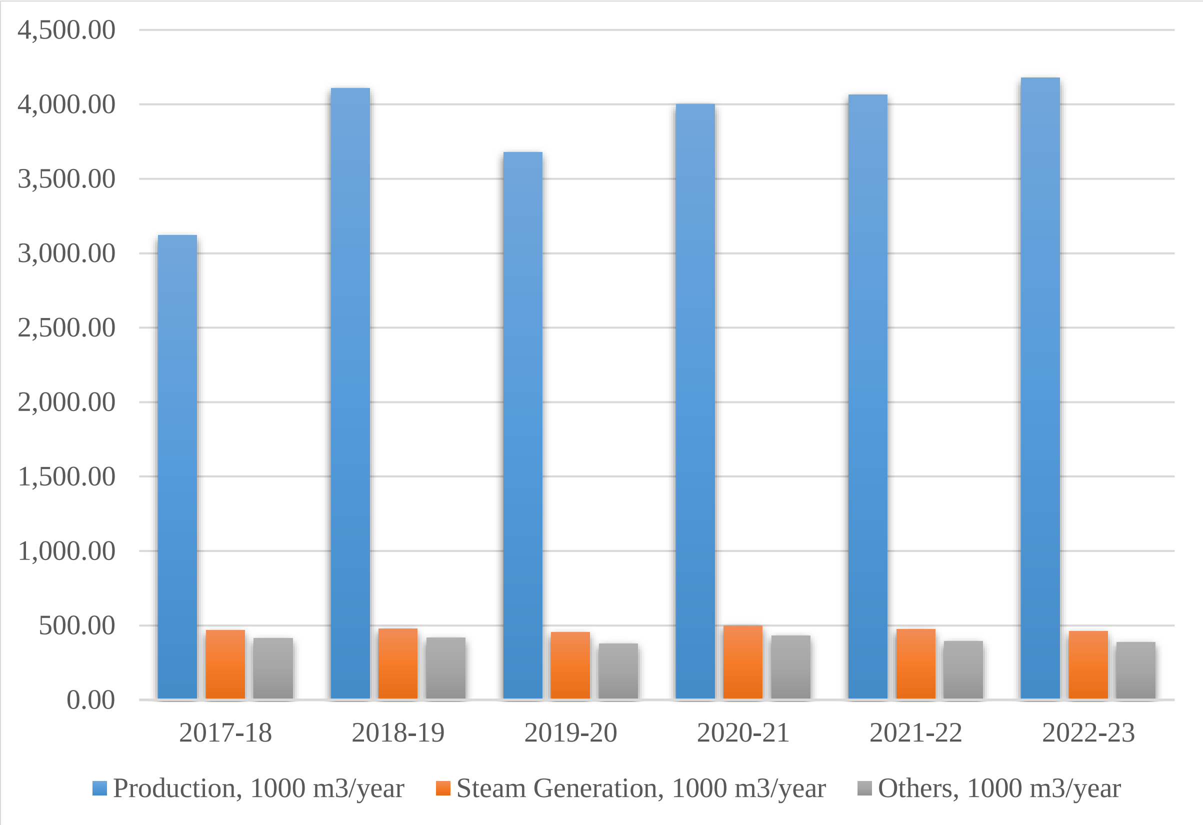


Figure 2.6.1: Share of Water Consumption Over the Years

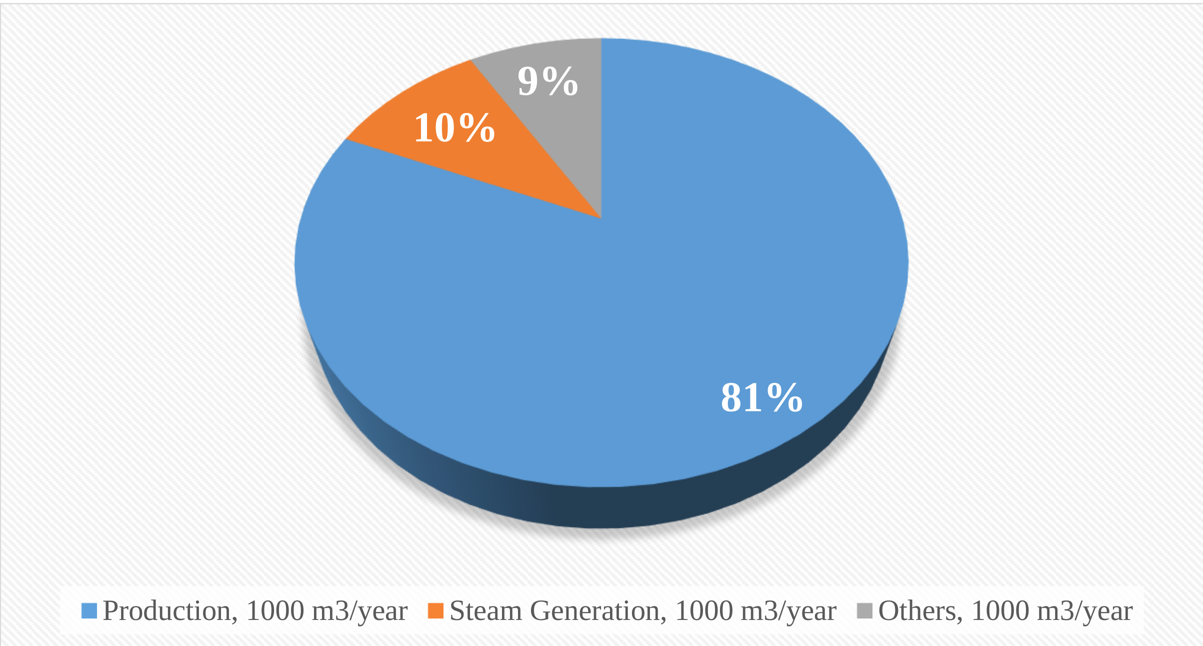


Figure 2.6.2: % Share of Water Consumption over the Fiscal Years 2017-18 to 2022-23

2.7 PERFORMANCE OF THE UTILITY BOILERS

Table 2.7.1: Boiler Data

S.N.	Parameter	Unit	Boiler-1	Boiler-2
1	NG Flow	kNm^3/h	6.87	6.87
2	BFW Pressure	$kg/cm^2(g)$	131.68	131.63
3	NG Pressure	$kg/cm^2(g)$	2.69	2.71
4	Steam Drum Pressure	$kg/cm^2(g)$	113.62	113.44
5	Secondary Superheater Outlet HP Steam Pressure	$kg/cm^2(g)$	109.24	109.46
6	Economizer inlet Pressure	$kg/cm^2(g)$	114.21	114.51
7	Economizer outlet Pressure	$kg/cm^2(g)$	113.62	113.44
8	Primary Superheater outlet Pressure	$kg/cm^2(g)$	118	118
9	Secondary Superheater inlet Pressure	$kg/cm^2(g)$	116	116
10	CBD Pressure	$kg/cm^2(g)$	113.6	113.44
11	Air Pressure	mmH_2O	465	415.46
12	FD fan air inlet Pressure	mmH_2O	516	540.07
13	O2 in Flue gas	%	2.4	2.6
14	Generated steam flow	t/h	90.41	90.93
15	CBD	t/h	0.9	1
16	Boiler feed water supply	t/h	95.4	91
17	Economizer inlet Temperature	°C	138.17	139.62
18	Economizer outlet Temperature	°C	197.48	202.4
19	Primary superheater inlet Temperature	°C	325.6	325.6
20	Primary Superheater outlet Temperature	°C	434.65	440.41
21	Secondary Superheater Outlet Temperature	°C	513.41	512.96
22	Flue gas Temperature (Before Economizer)	°C	386.53	393.55
23	Stack gas Temperature	°C	197.53	181.96
24	Secondary Superheater inlet Temperature	°C	361.92	359.27
25	CBD Temperature	°C	325.6	325.51

Table 2.7.2: Proximate and Ultimate Analysis of Fuel

Proximate Analysis of Fuel			Ultimate Analysis of Fuel			
Parameters	Molecular Weight	Mole %	Carbon Mole %	H_2 Mole %	N_2 Mole %	CO_2 Mole %
Methane	16	0.9664	0.7248	0.24		
Ethane	30	0.016822	0.0135	0.00		
Propane	44	0.005835	0.0048	0.00		
Butane	58	0.003237	0.0027	0.00		
Pentane	72	0.004874	0.0041	0.00		
Hexane	86	0.001339	0.0011	0.00		
Heptane	100	0.000657	0.0006	0.00		
Nitrogen	28	0.000303			0.0003	
Carbon dioxide	44	0.001485				0.0015
Total		1.00	0.7514	0.2477	0.0003	0.0015

Table 2.7.3: Measured Data During Flue Gas Analysis

Parameter	**Unit**	**Boiler 1**	**Boiler 2**
O_2	%	2.4	2.6
CO	ppm	22	25
CO_2	%	10.54	10.42
Stack Gas Temperature	°C	197.53	181.96
Ambient Temperature	°C	33.5	
Ambient Humidity	%	71.7	

Table 2.7.4: Parameters for Calculating Boiler Efficiency

	Unit	**Boiler-1**	**Boiler-2**
Excess air	%	12.9%	14.1%
Theoretical Air	kg/kg of NG	17.32	17.32
Flue Gas Mass Flow	kg/kg of NG	20.56	20.77
Heat Input (NG)	kcal/kg of gas	11,844 (as per provided data of KAFCO)	
Specific heat of flue gas	kcal/kg°C	0.25	

Table 2.7.5: Indirect Efficiency Calculation for the Utility Boilers

Boiler Losses	**Boiler-1**		**Boiler-1**	
Description	Output (kcal)	%	Output (kcal)	%
L1. Loss Due to Dry Flue Gas (Sensible Heat)	842.99	7.12	770.86	6.51
L2. Loss Due to Hydrogen in Fuel (H2)	1466.55	12.38	1450.93	12.25
L3. Loss Due to Moisture in Air (H_2O)	21.65	0.18	19.81	0.17
L4. Loss Due to Carbon Monoxide (CO)	0.00	0.00	0.00	0.00
L5. Loss Due to Radiation and other unaccounted	177.67	1.50	177.67	1.50
Indirect Efficiency (100-L1-L2-L3-L4-L5)	9335.54	78.82	9425.13	79.57
Average Efficiency of Boiler	79.20			

Chapter 3: Energy Conservation Measures (ECMs)

Reducing energy intensity in KAFCO will not only contribute to cost savings but also align with sustainability goals by minimizing environmental impact. Continuous improvement strategies, technological advancements, and best practices in energy management are essential for optimizing energy intensity in fertilizer manufacturing processes. Regular energy audits and monitoring can help identify opportunities for improvement and guide efforts to enhance energy efficiency. This process helps identify areas for improvement and implement best practices to improve energy efficiency.

ECM-1: Energy Saving Scope by Refurbishing/Modifying Feed Water

Current Practice: The exhaust temperature of all the boilers, currently, is higher than 180 °C resulting in an enormous amount of heat energy continuously losing.

Improvement Measure: Refurbish or modify (if necessary) the existing economizer with a competent one aiming to capture the maximum amount of unused heat. Based on the documentation provided by KAFCO, there is no sulphur content in the natural gas, so concerns regarding sulphur corrosion is irrelevant. Therefore, a stack temperature of 90 to 100 °C is technically feasible.

A snapshot of the cost and benefit analysis is provided in the table below. A detailed calculation is also shown in this section.

Table 2.7.1: Cost and Benefit Analysis for ECM-1

Investment	80,000,000.00	BDT
Annual Monetary Savings for the Two Boilers @BDT 22 per m^3	479,738,288.71	BDT/yr
Project Lifetime	15.00	Years
Simple Payback Period	0.17	Year
IRR	599	%
NPV	3,183,345,956	BDT

Table 2.7.2: Technical Analysis for ECM-1 (a) General Parameters (b) Individual Parameters for the Two Utility Boilers

(a)

Parameter	**Unit**	**Quantity**
Boiler Efficiency	%	79.20
LHV of NG	kCal/Nm^3	8,830.00
LHV of NG	kJ/kg	49,509.59
Density of NG	kg/m^3	0.7100
CO_2 Emission Factor	kg/MJ	0.0136
Cost of NG	BDT/m^3	22.00
Yearly Operation	h/yr	8,000.00
Enthalpy of Superheated Steam @ 108 kg/cm^2 , 513 °C	kJ/kg	3,398.00
Enthalpy of Feed Water @ 138 °C	kJ/kg	577.67
Atmospheric Pressure	kg/cm^2 (a)	1.03
Designed Mass of Steam Flow	kg/h	90,410.00
Correction Factor	-	0.60
Boiler Pressure	kg/cm^2 (a)	108.00
Steam Generation Capacity	kg/h	85,000.00
	lb/h	187,392.70

(b)

Parameter	**Unit**	**Boiler-1**	**Boiler-2**
Initial Stack Temperature	°C	197.53	181.96
Proposed Stack Temperature	°C	100.00	100.00
Flue Gas Exit Temperature after Boiler	°C	386.53	393.55
	°F	727.75	740.39
Feed water Temperature	°C	197.53	181.96

Parameter	Unit	Boiler-1	Boiler-2
Feed water Temperature after Economizer	°C	100.00	100.00
Temperature Increased in Economizer	°C	386.53	393.55
Feed water Mass flow	T/h	727.75	740.39
Enthalpy (saturated steam) @109 kg/cm^2	kcal/kg	138.17	139.62
	Btu/lb	197.48	202.40
Enthalpy of Feed Water	kcal/kg	59.31	62.78
	Btu/lb	95.40	91.00
Boiler Heat Output	Btu/h	812.00	812.00
	MMBtu/h	1,460.62	1,460.62
FROM Annexure-II, Recoverable Heat	MMBtu/h	138.17	139.62
Annual Fuel Saving	kJ/h	248.54	251.15
	kg/h	227,135,479.18	226,646,711.33
	kg/yr	227.14	226.65
	m^3/yr		
	BDT/yr	57.67	57.67
Currently, Heat Recovered By Feed Water	kJ/h	60,845,330.45	60,845,330.45
Net Heat Recovery Potential	kJ/h	14.71	14.71
Annual Fuel Saving	kg/h	117,671.17	117,671.17
	m^3/h	165,734.04	165,734.04
	m^3/yr	3,646,148.86	3,646,148.86
Annual Cost Saving	BDT/yr	23,651,167.32	23,880,256.40
Total Cost Saving in Two Utility Boilers	**BDT/yr**	**468,840,213.01**	
CO_2 Reduction	t-CO_2/yr	23,878.12	23,731.04
Total CO_2 Reduction	**t-CO_2/yr**	**47,609.16**	

Table 2.7.3: Economic Analysis for ECM-1

From the Previous Table, Recoverable Heat	60,845,330.45	kJ/h
Currently, Heat Recovered by Feed Water	23,765,711.86	kJ/h
Heat Saving Scope	37,079,618.59	kJ/h
Gas Saving by Refurbishing / Modifying Economizer	1339.50	m^3/h
Gas Saving Scope for the Two Boilers	2679.00	m^3/h
Annual Gas Saving @8000 Hours per Year Operation	21,431,980.07	m^3/yr
Annual Monetary Savings @BDT 22 per Cubic Meter	471,503,561.61	BDT/yr
Investment	80,000,000.00	BDT
Project Lifetime	15.00	Years
Simple Payback Period	0.17	Year
IRR	588.63	**%**
NPV	3,127,260,345.73	**BDT**

Table 2.7.4: NPV and IRR Calculations for ECM-1

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
0	80,000,000.00	-	-	(80,000,000.00)
1		600,000.00	471,503,561.61	470,903,561.61
2		600,000.00	471,503,561.61	470,903,561.61
3		600,000.00	471,503,561.61	470,903,561.61
4		600,000.00	471,503,561.61	470,903,561.61
5		600,000.00	471,503,561.61	470,903,561.61
6		600,000.00	471,503,561.61	470,903,561.61
7		600,000.00	471,503,561.61	470,903,561.61
8		600,000.00	471,503,561.61	470,903,561.61
9		600,000.00	471,503,561.61	470,903,561.61
10		600,000.00	471,503,561.61	470,903,561.61
11		600,000.00	471,503,561.61	470,903,561.61
12		600,000.00	471,503,561.61	470,903,561.61
13		600,000.00	471,503,561.61	470,903,561.61
14		600,000.00	471,503,561.61	470,903,561.61
15		600,000.00	471,503,561.61	470,903,561.61
			NPV	**3,127,260,345.73**
			IRR	**589%**

ECM-2: Heat Recovery by covering with Thermal Insulation of the Uninsulated Steam Valve and Flanges

Current Problem: During the visit, many steam valves and flanges of different sizes were observed uncovered with insulating materials throughout the KAFCO resulting in a large amount of heat energy continuously dissipating into surrounding which warming up working environment alongside.

Figure 2.7.1: Uninsulated Portions of Turbine Pump

IMPROVEMENT MEASURE: Properly cover with the thermal insulating materials to the bare steam valves, and flanges to prevent heat dissipation and save energy.

A snapshot of the cost and benefit analysis is provided in the table below. A detailed calculation is also shown in this section.

Table 2.7.1: Cost and Benefit Analysis for ECM-2

Investment	4,241,160.00	BDT/Yr
Annual Monetary Savings	27,127,570.23	BDT
Project Period	10	Years
Simple Payback Period	0.16	Year
NPV	149,035,662.04	BDT
IRR	639.63	%

Table 2.7.2: Technical Analysis for ECM-2

Parameter	**Unit**	**Value**
Assumptions for Calculation		
Bare Pipe Temperature	°C	150.00
Ambient Temperature	°C	30.00
Pipe Temperature after Insulation	°C	60.00
Thermal Insulation	%	89.00
Boiler Efficiency	%	78.09
Operating Time	Hr/Yr	8,000.00
Lower Heating Value of Fuel (NG)	MJ/kg	48,995.30
Lower Heating Value of Fuel (NG)	MJ/m^3	34,953.25
Density of Ng	kg/m^3	0.7134
Cost of NG	BDT/m^3	22.00
Effect		
Heat Loss Before Insulation	$kCal/Hr/m^2$	8,400
Heat Loss After Insulation	$kCal/Hr/m^2$	750.00

Parameter	Unit	Value
Heat Recovery	$kCal/Hr/m^2$	7,650.00
Fuel Saving per Square Meter	$m^3/Hr/m^2$	1.1736
	$m^3/Yr/m^2$	9,388.48
Monetary Saving per Square Meter	$BDT/Yr/m^2$	206,546.46
Total Uninsulated Surface Area (Estimated)	m²	131.34
Heat Loss Reduction Scope	kJ/Hr	4,205,850.19
	GJ/Year	33,646.80
Annual Fuel Saving	m^3/Year	1,233,071.37
Monetary Saving	BDT/Year	27,127,570.23
Insulation Price	BDT/SFT	3,000.00
Investment	BDT	4,241,160.00
Project lifetime	Year	10.00
Payback period	Year	0.16
IRR	**%**	**639.63%**
NPV	**BDT**	**149,035,662.04**

Calculation Formula:

Heat Recovery = Bare Pipe Heat Loss ($kCal/Yr/m^2$) - Insulated Pipe Heat Loss ($kCal/Yr/m^2$)

Fuel Saving = Heat Recovery/(Boiler Efficiency × Lower Heating Value)

Table 2.7.3: NPV and IRR Calculations for ECM-2

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
0	4,241,160.00	0	0	(4,241,160.00)
1	0	0	27,127,570.23	27,127,570.23
2	0	0	27,127,570.23	27,127,570.23
3	0	0	27,127,570.23	27,127,570.23

4	0	0	27,127,570.23	27,127,570.23
5	0	0	27,127,570.23	27,127,570.23
6	0	0	27,127,570.23	27,127,570.23
7	0	0	27,127,570.23	27,127,570.23
8	0	0	27,127,570.23	27,127,570.23
9	0	0	27,127,570.23	27,127,570.23
10	0	0	27,127,570.23	27,127,570.23
			NPV	**149,035,662.04**
			IRR	**639.63%**

ECM-3: **Reformer and Auxiliary Boiler of NH_3 Surface Heat Loss Reduction**

CURRENT PRACTICE: It was observed that a large portion of the surfaces of both NH_3 plant reformer and aux. boiler are not properly covered with insulating materials which elevated the surface temperature of NH_3 Plant Reformer & Aux. Boiler up to approximately 150 °C, resulting in a substantial amount of continuous surrounding heat dissipation, and consequently, warming the working environment.

(a) (b)

Figure 0.1: Reformer Surface Heat Loss

IMPROVEMENT MEASURE: Heat loss can be reduced by covering the uninsulated surface with proper insulating material aiming to bring down surface temperature up to 60 °C which will assist in saving a significant amount of energy as well as bring down surrounding temperature.

KAFCO informed that the heat sensitive color code on transfer line is a standard design practice provided by the Process Licensor; which is a safety measure to understand whether there is any problem in the refractory materials. If the line is covered with insulating materials, they would not be able understand the condition of the refractory.

Therefore, the auditors recommend that KAFCO should communicate with the Process Licensors about the energy loss and implement measure that would bring the loss to a minimum.

ECM-4: **Installation of Inlet Guide Vane (IGV) at the Inlet of Air Compressor for Controlling the Air Intake**

CURRENT PRACTICE: Air Compressors are critical components in any industrial process, and their efficient operation is essential for maintaining system stability and performance. In KAFCO, when the process demands to operate at partial load, Air Compressors are prone to surge, a condition that can cause significant damage. Anti-surge valves are commonly used to prevent surges by recycling gas from the discharge to the suction. A huge loss occurred in the compressor when it is running in partial load.

IMPROVEMENT MEASURE:

Option-1: The integration of Inlet Guide Vanes (IGVs) can enhance compressor performance and stability under these conditions. IGVs are adjustable vanes that can be located at the compressor inlet. They control the angle of the incoming air, thereby influencing the flow characteristics and pressure rise within the compressor. By adjusting the IGVs, the compressor can operate more efficiently across a range of loads. When a compressor operates at partial load, the combination of IGVs and anti-surge valves can provide a robust solution for surge prevention and efficiency improvement. The IGVs can be adjusted to optimize the inlet flow, while the anti-surge valve ensures that the compressor remains within safe operating limits by recycling gas as needed.

Option-2: As the compressor is running partially for most of the time due to low production demand, it brings about huge loss from blowing off the high-pressure air as an anti-surge measure. KAFCO authority can consider installing low-capacity compressor (50-60% of the current capacity) to tackle the partial load demand.

A snapshot of the cost and benefit analysis is provided in the table below for option-1. A detailed calculation is also shown in this section.

Table 0.1: Cost and Benefit Analysis for ECM-4

Investment	3,000,000.00	BDT
Annual Monetary Savings	2,180,923.74	BDT
Project Lifetime	15	Years
Simple Payback period	1.38	Year
IRR	72.72	%
NPV	11,853,976.07	BDT

Table 0.2: Technical Analysis and Financial Analysis for ECM-4

Parameter	**Unit**	**Value**
Operation Time	Hr/Yr	8,000
Cost of Compressed Air	BDT/m^3/Hr	125.00
Boiler Efficiency	%	78.09
Lower Heating Value of Fuel (NG)	kJ/m^3	34953.25
Cost of NG	BDT/m^3	22.00
Useful Factor	-	0.40
Design Pressure of Air Compressor	bar a	38.00
Design Temperature of Air Compressor	°C	181.00
Pressure at maximum Load	bar a	34.00
Temperature at maximum Load	°C	129.00
Pressure at Partial Load (avg.)	bar a	28.80
Temperature at partial load	°C	131.00
Current Power consumption per hour from Turbine	kWh	1,878.95
Power consumption per hour when IGV is used	kWh	1,785.00
Hourly Energy Saving	kWh	93.95
Yearly Energy Saving	kWh	751,578.95
Fuel Saving	m^3	99,132.90
Annual Monetary Saving	BDT/Yr	2,180,923.74
Investment	BDT	3,000,000.00
Project lifetime	Years	15.00
Payback Period	Year	1.38
IRR	**%**	**72.72%**
NPV	**BDT**	**11,853,976.07**

Table 0.3: NPV and IRR Calculations for ECM-4

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
-	3,000,000.00	-	-	(3,000,000.00)
1		-	2,180,923.74	2,180,923.74
2		-	2,180,923.74	2,180,923.74
3			2,180,923.74	2,180,923.74
4		-	2,180,923.74	2,180,923.74
5		-	2,180,923.74	2,180,923.74
6		-	2,180,923.74	2,180,923.74
7			2,180,923.74	2,180,923.74
8		-	2,180,923.74	2,180,923.74
9		-	2,180,923.74	2,180,923.74
10		-	2,180,923.74	2,180,923.74
11			2,180,923.74	2,180,923.74
12		-	2,180,923.74	2,180,923.74
13		-	2,180,923.74	2,180,923.74
14		-	2,180,923.74	2,180,923.74
15			2,180,923.74	2,180,923.74
			NPV	**11,853,976.07**
			IRR	**72.72%**

ECM-5: **Installation of Rooftop Solar Panel**

CURRENT PROBLEM: Production, utility, and household require power consumption which comes at the cost of fossil fuel which is dwindling at a faster rate. It's a global concern to minimize the consumption of fossil fuels. Different building roofs have the potential to install rooftop solar.

IMPROVEMENT MEASURE: It will be prudent to install solar panels in empty areas or rooftops. Modern technology allows rooftop solar panels with features suitable to be installed on the metal roofs of industrial and commercial buildings. Utility Consumption can be reduced. Renewable energy can be exported to the National Grid.

For indicative purposes, we have considered the maintenance workshop. and the results are down below:

Table 0.1: Cost and Benefit Analysis for ECM-5

Investment	50,000,000.00	BDT
Annual Monetary Savings (Earnings)	7,568,901.90	BDT
Project Lifetime	25	Years
Simple Payback period	6.61	Year
IRR	14.64	%
NPV	9,363,950.53	BDT

Table 0.2: Technical Information for ECM-5

Parameter	**Unit**	**Value**
No of Modules	Pieces	954
Rated Power (PnomDC)	Wp	600
Solar PV System Footprint	m^2	2,464
Annual Specific Yield	kWp	572.00
System Lifetime	Years	25
Number of Inverters	Pieces	5
Rated Power (PnomAC)	kWac	500.00
Pnom Ratio	-	1.15

Parameter	Unit	Value
Annual Energy Production	kWh	800,942.00
Project Engineering, Procurement, and Construction (EPC) Cost	BDT	50,000,000.00
Levelized Tariff for Roof Top Solar PV Electricity	BDT/kWh	9.45
Yearly Cost Savings	BDT	7,568,901.9
Investment	BDT	50,000,000.00
Project Lifetime	Years	25
Payback Period	Years	6.61
IRR	**%**	**14.64%**
NPV	**BDT**	**9,363,950.53**

Table 0.3: NPV and IRR Calculations for ECM-5

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
-	50,000,000.00	-	-	(50,000,000.00)
1	-	-	7,568,901.90	7,568,901.90
2	-	-	7,568,901.90	7,568,901.90
3	-	-	7,568,901.90	7,568,901.90
4	-	-	7,568,901.90	7,568,901.90
5	-	-	7,568,901.90	7,568,901.90
6	-	-	7,568,901.90	7,568,901.90
7	-	-	7,568,901.90	7,568,901.90
8	-	-	7,568,901.90	7,568,901.90
9	-	-	7,568,901.90	7,568,901.90
10	-	-	7,568,901.90	7,568,901.90
11	-	-	7,568,901.90	7,568,901.90
12	-	-	7,568,901.90	7,568,901.90
13	-	-	7,568,901.90	7,568,901.90
14	-	-	7,568,901.90	7,568,901.90

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
15	-	-	7,568,901.90	7,568,901.90
16	-	-	7,568,901.90	7,568,901.90
17	-	-	7,568,901.90	7,568,901.90
18	-	-	7,568,901.90	7,568,901.90
19	-	-	7,568,901.90	7,568,901.90
20	-	-	7,568,901.90	7,568,901.90
21	-	-	7,568,901.90	7,568,901.90
22	-	-	7,568,901.90	7,568,901.90
23	-	-	7,568,901.90	7,568,901.90
24	-	-	7,568,901.90	7,568,901.90
25	-	-	7,568,901.90	7,568,901.90
			NPV	**9,363,950.53**
			IRR	**14.64%**

The detailed simulation is attached in Annexure-III.

ECM-6: Energy Conservation by Replacing the Cooling Tower's Aluminum Fans with Fiberglass Reinforced Plastic (FRP) Fans

CURRENT PRACTICE: The cooling tower induction draft fans are now aluminum made and that is why those are less aerodynamically efficient. The FRP fans may be used in place of the aluminum fans.

IMPROVEMENT MEASURE: Replace the fans with FRP fans of a more aerodynamically efficient design.

One of the basic design criteria for blade design is to produce uniform air flow over the entire plane of the fan. One of the aerodynamic principles involved is that the work done at any radius along the blade is a function of blade width, angle of attack and tangential velocity squared. The "angle of attack" in air foil design dictates the amount of blade twist required at any particular radius along the blade. It follows that as a point on the blade decreases from tip toward the hub the tangential velocity sharply decreases and in order to produce uniform air-flow, the blade width and twist must increase. If the blade chord cannot increase in width, the twist must be increased to compensate. With an extruded blade the twist is created by mechanically yielding the blade to a prescribed degree. Due to limits in elasticity only limited twist can be created. In a molded blade there is no such limitation to chord width or twist so the "ideal" blade can be more closely approached. (Reference: Robert C. Monroe, IMPROVING COOLING TOWER FAN SYSTEM EFFICIENCIES).

The purpose of a cooling tower fan is to move a specified quantity of air through the system. The fan has to overcome the system resistance, which is defined as the pressure loss, to move the air. The fan output or work done by the fan is the product of air flow and the pressure loss. The fan output and kW input determine the fan efficiency. The fan efficiency in turn is greatly dependent on the profile of the blade. Blades include:

- Metallic blades, which are manufactured by extrusion or casting processes and therefore it is difficult to produce ideal aerodynamic profiles.
- Fiber reinforced plastic (FRP) blades are normally hand molded which makes it easier to produce an optimum aerodynamic profile tailored to specific duty conditions. Because FRP fans are light, they need a low starting torque requiring a lower HP motor, the lives of the gear box, motor and bearing is increased, and maintenance is easier. 85-92% efficiency can be achieved with blades with an aerodynamic profile, optimum twist, taper and a high coefficient of lift to coefficient of drop ratio. However, this efficiency is drastically affected by factors such as tip clearance, obstacles to air flow and inlet shape, etc. Cases reported

where metallic or glass fiber reinforced plastic fan blades have been replaced by efficient hollow FRP blades. The resulting fan energy savings were in the order of magnitude of 20-30% with simple payback period of 6 to 7 months (NPC). (Reference: Keerthi R Lekshmi, Victor Jose; PERFORMANCE ANALYSIS OF AN INDUSTRIAL COOLING TOWER.)

A snapshot of the cost and benefit analysis is provided in the table below. A detailed calculation is also shown in this section.

Table 0.1: Cost and Benefit Analysis for ECM-6

Investment	1,500,000.00	BDT
Annual Monetary Savings	287,277.14	BDT/Yr
Project lifetime	15	Years
Payback period	5.22	Year
IRR	17.43	%
NPV	456,605.67	BDT

Table 0.2: Technical Analysis for ECM-6

Parameter	**Unit**	**Value**
Boiler Efficiency	%	78.09
Lower Heating Value of NG	kJ/m^3	34953.25
Cost of NG	BDT/m^3	22.00
Total Number of Fan	Piece	10
Total Power Consumption/Hr	kWh	1,100.00
Monthly Power Consumption	kWh	33,000.00
Yearly Power Consumption	kWh	396,000.00
Power Savings through FRP Fan	%	25
Yearly Total Power Savings	kWh	99,000.00
Lifetime of Fan	Years	15
Fuel Saving	m^3	13,058.05
Yearly Cost Savings	BDT	287,277.14
Material Cost	BDT	1,000,000.00

Parameter	Unit	Value
Installation Cost	BDT	500,000.00
Total Project Cost	BDT	1,500,000.00
Investment	BDT	1,500,000.00
Project Lifetime	Years	15
Simple Payback Period	Years	5.22
IRR	**%**	**17.43%**
NPV	**BDT**	**456,605.67**

Table 0.3: NPV and IRR Calculations for ECM-6

Year	Investment Cost	Operating Cost	Savings	Net Cash Flow
-	1,500,000.00	-	-	(1,500,000.00)
1	-	-	287,277.14	287,277.14
2	-	-	287,277.14	287,277.14
3	-	-	287,277.14	287,277.14
4	-	-	287,277.14	287,277.14
5	-	-	287,277.14	287,277.14
6	-	-	287,277.14	287,277.14
7	-	-	287,277.14	287,277.14
8	-	-	287,277.14	287,277.14
9	-	-	287,277.14	287,277.14
10	-	-	287,277.14	287,277.14
11	-	-	287,277.14	287,277.14
12	-	-	287,277.14	287,277.14
13	-	-	287,277.14	287,277.14
14	-	-	287,277.14	287,277.14
15	-	-	287,277.14	287,277.14
			NPV	**456,605.67**
			IRR	**17.43%**

CHAPTER 4: CONCLUSION

The energy audit conducted at KAFCO aimed to assess the current energy consumption, identify inefficiencies, and propose strategies for enhancing energy efficiency and sustainability. The audit, carried out over a week, involved a comprehensive analysis of energy systems, processes, and management practices. The audit was aimed to assess the performance of existing systems, highlight inefficiencies, and recommend practical solutions for optimizing energy use.

The overall energy management system of KAFCO is very good. The specific energy consumption of both Ammonia and Urea is better than the global average value. There was almost no visible leak in steam and compressed air distribution system. A few saving opportunities were identified implementation of which will further increase the performance of KAFCO. KAFCO is suggested to assess the feasibility of implementing these measures and take actions accordingly.

ANNEXURES

ANNEXURE-I: PORTABLE INSTRUMENTS USED FOR MEASUREMENTS

Table A1: List of Portable Instruments Used for Measurements

Sl. No	Description	Manufacturer	Model Name	Quantity
1	Ultrasonic Flow Meter	Endress Hauser	Prosonic DMTF (M+L)	1 set
2	Thermo-Hygrometer	TESTO	TESTO 625	1 pc
3	Combustion Air Analyzer	TESTO	TESTO 320	1 set
4	Infrared Temperature Meter	KIMO	KIRAY100	1 pc
5	Power Quality Analyzer	HIOKI	PW3198	1 set
6	Thermal Imaging Camera	FLIR	C8940	1 pc

Annexure-II: Used in the Calculation for ECM-1

Recoverable Heat from Boiler Flue Gases

Initial Stack Gas Temperature, °F	Recoverable Heat, MMBtu/hr			
	Boiler Thermal Output, MMBtu/hr			
	25	50	100	200
400	1.3	2.6	5.3	10.6
500	2.3	4.6	9.2	18.4
600	3.3	6.5	13.0	26.1

Based on natural gas fuel, 15% excess air, and a final stack temperature of 250˚F.

Extrapolation, {y=b+(x-a)*(d-b)/(c-a)}	
a	500
b	29.56
c	600
d	41.93
x	727.27
y	57.6733

Ref.: Improving Steam System Performance, A Sourcebook for Industry, Energy Efficiency and Renewable Energy, U.S. Department of Energy

Annexure-III: Simulation Report for Installation of Rooftop Solar Panel

Version 7.4.7

PVSYST
PHOTOVOLTAIC SOFTWARE

PVsyst - Simulation report

Grid-Connected System

Project: KAFCO Rooftop Solar

Variant: New simulation variant

No 3D scene defined, no shadings

System power: 572 kWp

KAFCO - Bangladesh

Project summary

Geographical Site
KAFCO
Bangladesh

Situation

Latitude	22.28 °N
Longitude	91.81 °E
Altitude	8 m
Time zone	UTC+6

Project settings

Albedo	0.20

Weather data
KAFCO
Meteonorm 8.1 (1991-2012), Sat=100% - Synthetic

System summary

Grid-Connected System

No 3D scene defined, no shadings

PV Field Orientation

Fixed planes	2 orientations
Tilts/azimuths	5 / -30 °
	5 / -150 °

Near Shadings
No Shadings

User's needs
Unlimited load (grid)

System information

PV Array

Nb. of modules	954 units
Pnom total	572 kWp

Inverters

Nb. of units	5 units
Pnom total	500 kWac
Pnom ratio	1.145

Results summary

Produced Energy	800942 kWh/year	Specific production	1399 kWh/kWp/year	Perf. Ratio PR	86.78 %

General parameters

Grid-Connected System — **No 3D scene defined, no shadings**

PV Field Orientation

Orientation
Fixed planes 2 orientations
Tilts/azimuths 5 / -30 °
5 / -150 °

Sheds configuration
No 3D scene defined

Models used
Transposition Perez
Diffuse Perez, Meteonorm
Circumsolar separate

Horizon
Free Horizon

Near Shadings
No Shadings

User's needs
Unlimited load (grid)

PV Array Characteristics

PV module
Manufacturer Longi Solar
Model LR5-72HTH-600M
(Original PVsyst database)
Unit Nom. Power 600 Wp
Number of PV modules 954 units
Nominal (STC) 572 kWp
Modules 53 string x 18 In series
At operating cond. (50°C)
Pmpp 533 kWp
U mpp 728 V
I mpp 732 A

Inverter
Manufacturer Huawei Technologies
Model SUN2000-100KTL-M1-480Vac
(Original PVsyst database)
Unit Nom. Power 100 kWac
Number of inverters 5 units
Total power 500 kWac
Operating voltage 200-1000 V
Max. power (=>40°C) 110 kWac
Pnom ratio (DC:AC) 1.14
Power sharing within this inverter

Total PV power
Nominal (STC) 572 kWp
Total 954 modules
Module area 2464 m²
Cell area 2275 m²

Total inverter power
Total power 500 kWac
Max. power 550 kWac
Number of inverters 5 units
Pnom ratio 1.14

Array losses

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 20.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 16 mΩ
Loss Fraction 1.5 % at STC

Module Quality Loss
Loss Fraction -0.8 %

Module mismatch losses
Loss Fraction 2.0 % at MPP

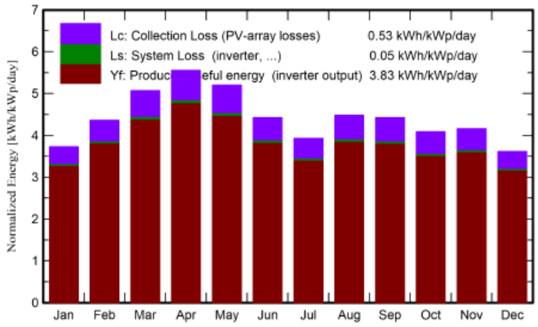
IAM loss factor
Incidence effect (IAM): Fresnel, AR coating, n(glass)=1.526, n(AR)=1.290

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.999	0.987	0.962	0.892	0.816	0.681	0.440	0.000

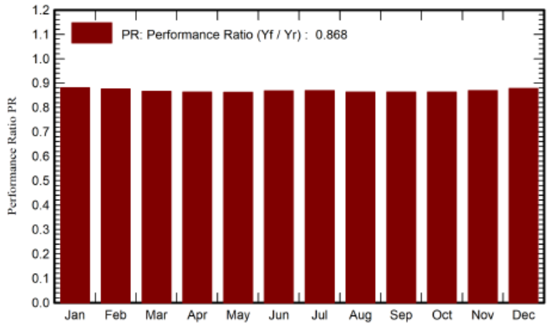
Main results

System Production
Produced Energy 800942 kWh/year
Specific production 1399 kWh/kWp/year
Perf. Ratio PR 86.78 %

Normalized productions (per installed kWp)



Performance Ratio PR



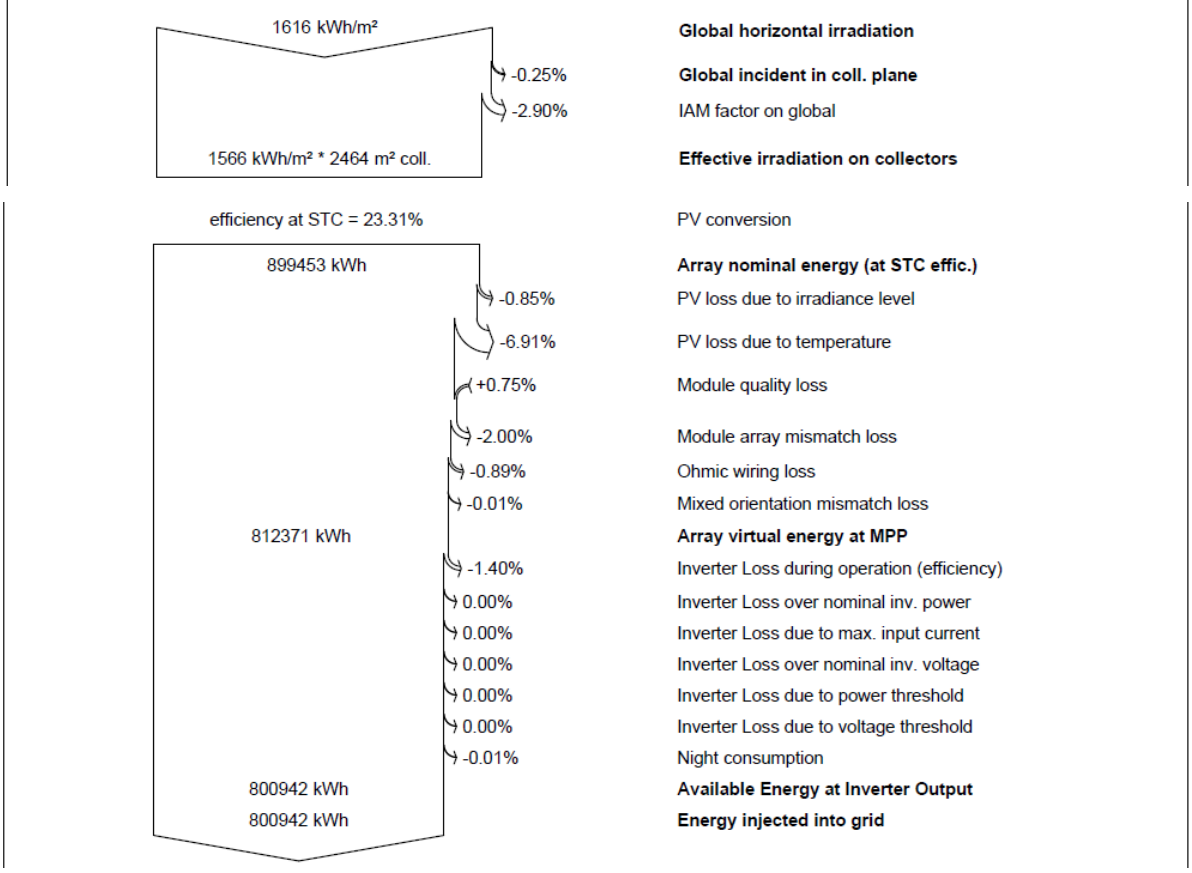
Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	115.9	60.41	21.05	115.6	111.2	59092	58305	0.881
February	122.4	64.28	23.98	122.2	118.5	62057	61210	0.875
March	157.5	80.04	26.90	157.2	153.4	79114	77982	0.867
April	166.9	89.25	28.45	166.5	162.6	83439	82245	0.863
May	161.4	94.79	29.25	161.4	157.5	80768	79603	0.862
June	133.2	89.64	28.31	132.6	129.1	66897	65952	0.869
July	122.2	89.10	28.26	121.8	118.3	61467	60604	0.869
August	139.1	81.99	28.50	138.8	135.2	69579	68578	0.863
September	133.0	72.69	28.29	132.6	129.0	66452	65492	0.863
October	127.2	64.60	28.26	126.7	122.8	63454	62556	0.862
November	125.1	53.55	25.48	124.7	120.5	62952	62083	0.870
December	112.4	54.76	22.45	112.1	107.8	57100	56332	0.878
Year	1616.3	895.11	26.61	1612.3	1565.7	812371	800942	0.868

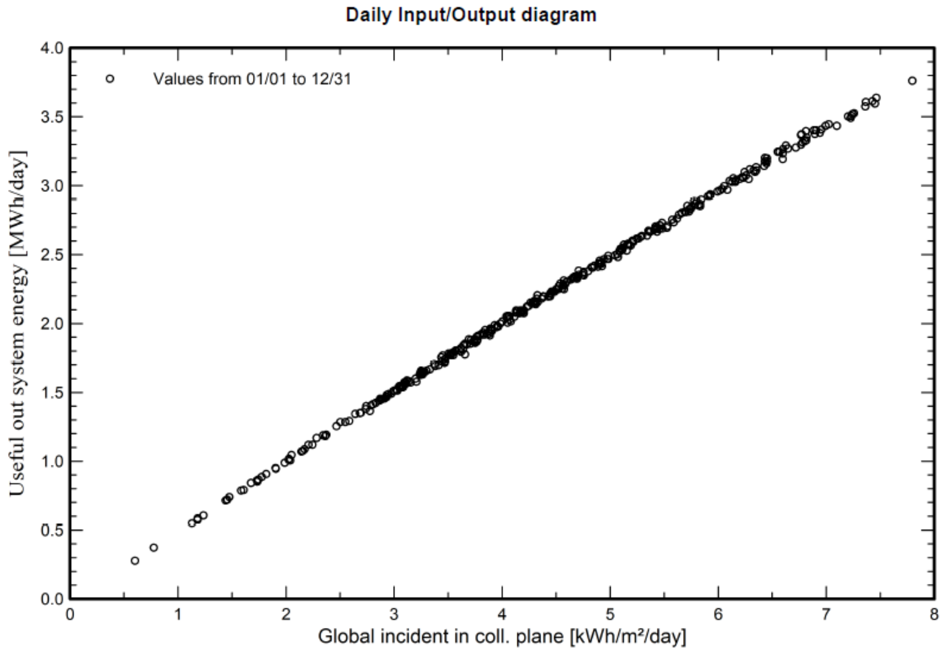
Legends

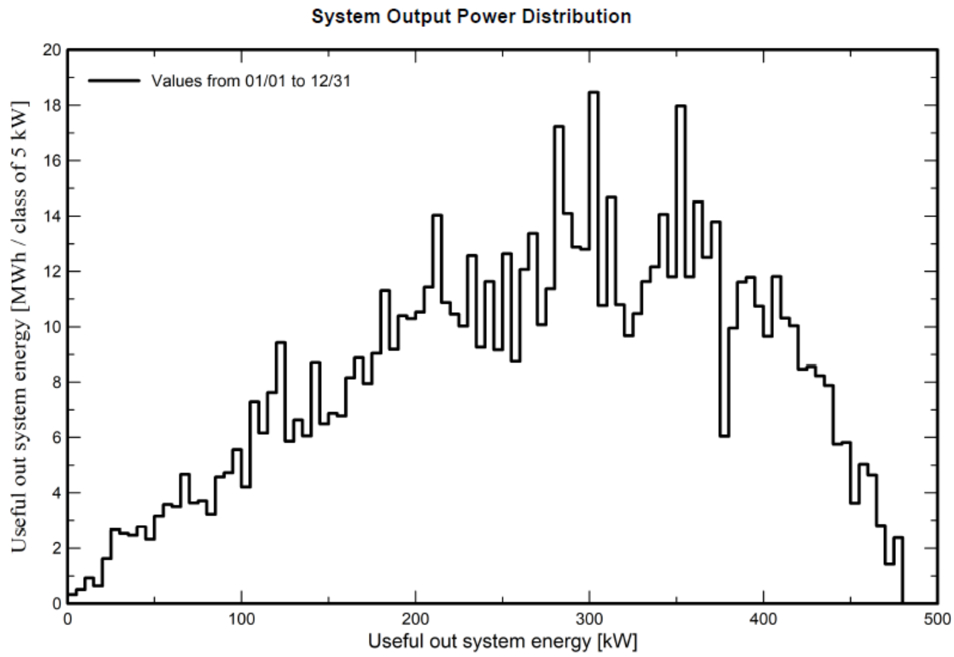
GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

Loss diagram



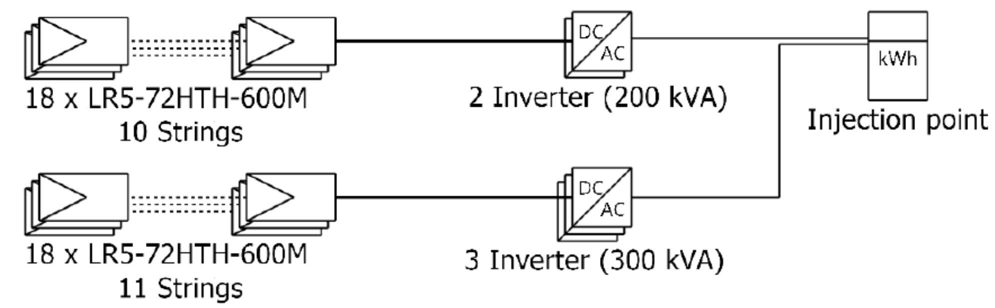
Predef. graphs





Single-line diagram

PVsyst V7.4.7
VC0, Simulation date:
09/01/24 17:24
with V7.4.7



PV module	LR5-72HTH-600M
Inverter	SUN2000-100KTL-M1-480Vac
String	18 x LR5-72HTH-600M

KAFCO Rooftop Solar

VC0 : New simulation variant

09/01/24