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BUSINESS COUNCIL FOR SUSTAINABLE DEVELOPMENT ZIMBABWE

ENERGY AND WATER MANAGEMENT MANUAL

for Industrial Sector in Zimbabwe

DRAFT

Prepared by

pwc

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CLIMATE TECHNOLOGY CENTRE & NETWORK

Under the project

Technical Assistance for piloting rapid uptake of industrial energy efficiency and efficient water utilization in the industrial sector in Zimbabwe

Prepared by

pwc

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Foreword

Zimbabwe is facing challenges to manage its water resources because of the adverse effects of climate change on the country's water supply. At the same time the energy supply often cannot meet the industry's demand, thus creating a strain on the power grid. Previous studies, indicating a high resource efficiency improvement potential in key industries in the country, have triggered various policy initiatives. However, these initiatives could not be implemented successfully due to a number of barriers.

The Climate Technology Centre and Network (CTCN), the implementation arm of the United Nations Framework Convention on Climate Change (UNFCCC) Technology Mechanism, promotes the accelerated transfer of technologies for energy-efficient, low-carbon and climate-resilient development. As nations around the world seek to fulfil their development goals in an increasingly sustainable and environmentally sound manner, the CTCN aims to serve as a trusted partner by providing expert policy and technology support. At the request of National Designated Entities (NDEs), the Centre harnesses the expertise of its global network of over 400 institutions to deliver tailored assistance and capacity building in a broad range of sectors including agriculture, energy, transport, water and waste management.

In response to Zimbabwe's request for technical assistance (TA) for piloting rapid uptake of industrial energy efficiency and efficient water utilization in the industrial sector in Zimbabwe the CTCN, collaborated with Zimbabwean NDE (Climate Change Management Department), and other key national counterparts including the Ministry of Environment, Water and Climate; the Ministry of Energy and Power Development; the Ministry of Industry and Commerce; Standards Association of Zimbabwe; Zimbabwe Energy Regulatory Authority and Business Council for Sustainable Development Zimbabwe (BCSDZ) to execute the technical assistance through PricewaterhouseCoopers (PwC), India.

We congratulate the team from PwC for putting such valuable information together in one place. We are confident that the stakeholders in the industry sector in Zimbabwe will take advantage of this publication and lead the industry sector towards sustainable and resource efficient production.

Sincerely,

Jukka Uosukainen
Director, Climate Technology Centre and Network

Preface

The industrial sector plays a pivotal role in the overall economic development, employment creation and effective reduction in poverty of the country. Zimbabwe's manufacturing sector contributes nearly 10% to the country's GDP. The capacity utilization of the sector has been on the rise in recent years. Considering vintage of technology and present practices, the energy and water utilization in the industries is quite inefficient. This can be attributed to inadequate knowledge and capacity of industry sector. The overarching goal of the technical assistance by CTCN/UNIDO is to create and showcase examples of successful resource efficiency improvements, which can be replicated by local technical staff to benefit industries nationwide.

PricewaterhouseCoopers (PwC) followed a systematic approach with a number of key steps towards the preparation of the manual on energy and water management for industry sector in Zimbabwe. Detailed energy audit of 10 shortlisted industries representing five sectors (agrochemical, cables, cement, food & beverages and mining) were conducted. The audit helped in arriving at the baseline energy and water performance indicators as well as in identifying energy and water efficiency improvements. Primary and secondary research was carried to identify energy and water efficient technology options and best operating practices available at national and international level. The identified technology options were further validated through consultation with industry and experts.

The manual on energy and water management for industry sector in Zimbabwe offers comprehensive guidance to stakeholders looking to get insights in energy and water management in industry. The manual provides introduction to key performance indicators and its importance for energy and water. Data management and analysis is presented in depth, followed by energy and water management with reference to technology, retrofits and best operating practices. The manual further describes financial analysis important for selecting energy and water efficiency improvement option for implementation.

The industrial sector in Zimbabwe and other key stakeholders such as government departments, technology suppliers and experts would find this Manual on Energy and Water Management useful for promoting resource efficiency in individual industry.

Sincerely,

Amit Kumar
Partner, PricewaterhouseCoopers India

Acknowledgement

PricewaterhouseCoopers (PwC) expresses its sincere gratitude to United Nations Industrial Development Organization (UNIDO) and Climate Technology Centre & Network (CTCN) for vesting its confidence in PwC for carrying out this prestigious "*technical assistance for piloting rapid uptake of industrial energy efficiency and efficient water utilization in the industrial sector in Zimbabwe*". We express our sincere thanks to Mr. Federico Villatico Campbell (Regional Manager, CTCN), Mr. Rajiv Garg (Regional Manager, CTCN), and Mr. Tichaona Mushayandebvu (Country Representative, UNIDO) for coordinating and steering the project.

PwC is indebted to the progressive management of the following shortlisted demonstration industries for their support, guidance and cooperation in conducting detailed energy and water audit, and supply side renewable energy assessment study of their facilities.

- CAFCA Limited, Harare
- Delta Beverages Lagers Plant, Bulawayo
- Hippo Valley Estates, Hippo Valley
- Lafarge Cement Zimbabwe, Harare
- Mimosa Mining Company
- Muriel Processing Plant
- Murowa Diamonds
- Schweppes Zimbabwe Limited
- Windmill Private Limited
- ZFC Limited

We take this opportunity to express our deep appreciation for the support and guidance extended by Mr. Elisha N Moyo, Principal Climate Change Researcher, Climate Change Management Department (National Designated Entity), Ministry of Environment, Water and Climate, Government of Zimbabwe.

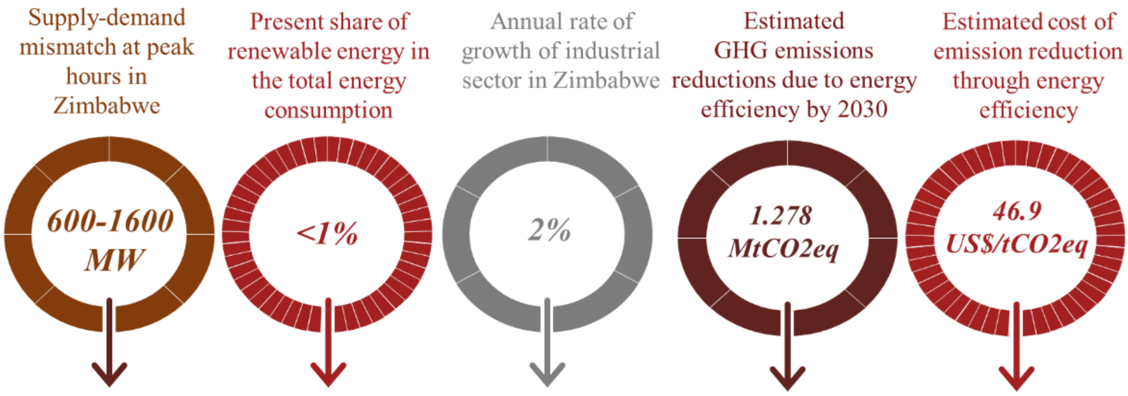
We would like thank the following stakeholders for their support and valuable inputs the Ministry of Energy and Power Development; the Ministry of Industry and Commerce; Standards Association of Zimbabwe; and Zimbabwe Energy Regulatory Authority.

Last but not the least, our sincere thanks to Mr. Tawanda Muzamwese, Executive Director, Business Council for Sustainable Development Zimbabwe for his full cooperation and support throughout the technical assistance.

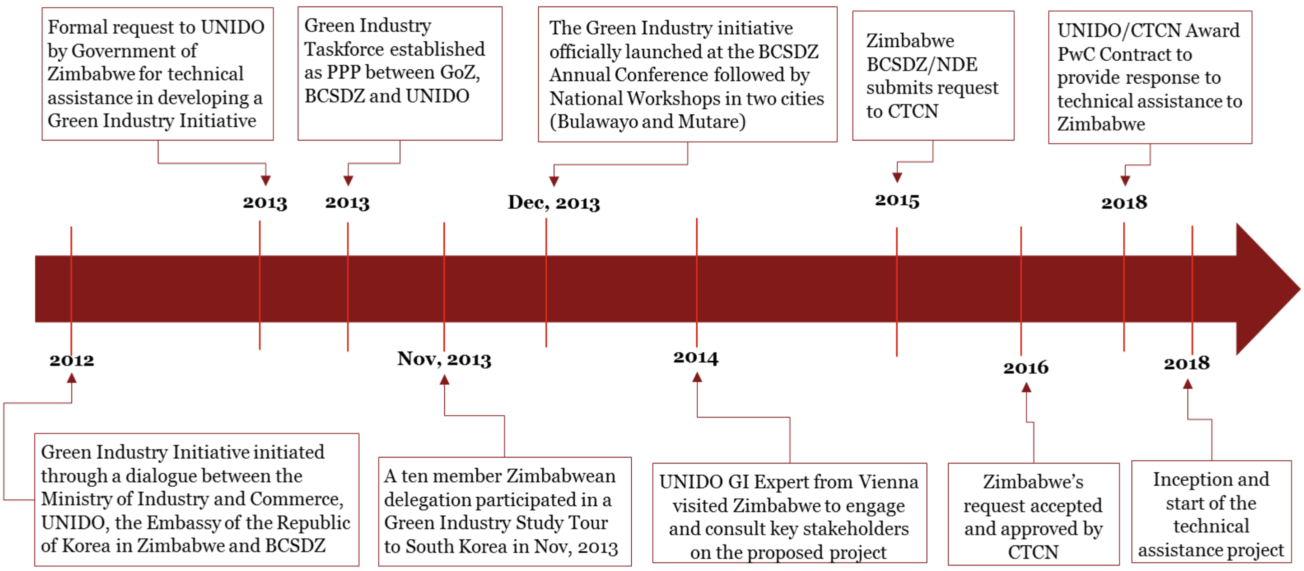
Project Background

Brief about the project

Zimbabwe is presently facing a deficit of key resources, namely, power and water to meet its demand. The water supply of the country has been affected drastically by the adverse effects of climate change. The prevailing power deficit leads to unmet demand/load shedding in end-use sectors including industries. Industrial sector is one of the major contributors to the national energy consumption. The key indicators of Zimbabwe are presented in figure.



The total available water for Zimbabwe is around 20 million mega-litres (in the form of surface and underground water). After the agricultural sector, water use is highest in the urban, industrial and institutional sector (15%). Limited monitoring and measurement of water and energy use, outdated equipment and inefficient processes have resulted in energy and water consumption well above global industry benchmarks. Zimbabwe is experiencing water scarcity, which affects industrial production. Presently, the energy demand is growing gradually at 2% annually. However, Zimbabwe's 3rd National Communication to UNFCCC predicts that manufacturing sector would be among the biggest consumers of electricity by 2030. With reference to the background of the country the genesis of the Technical Assistance is shown in figure.



Objectives of the Technical Assistance

The objective of the Technical Assistance is to identify energy, water efficiency and management improvement potential in ten selected demonstration companies and create capacities to replicate and implement such interventions autonomously in companies across Zimbabwe in the future. In the medium term it is expected that this will lead to a reduction of energy and water consumption as well as greenhouse gas emissions of the ten demonstration companies. At the same time, the expected gains from the increased profitability will and strengthen the competitiveness of the respective industries. Main objectives are highlighted in figure.

Objectives

- *Identify energy, water efficiency and management improvement potential in 10 selected pilot companies*
- *Create capacities to replicate and implement such interventions in companies across Zimbabwe in the future*

The overarching goal is to create and showcase examples of successful resource efficiency improvements, which can be replicated by local technical staff to benefit industries nationwide.

1	Identification and selection of ten pilot companies for energy and water efficiency audits
2	Execution of energy and water efficiency audits in the ten selected pilot companies
3	Analysis of renewable energy supply side opportunities for each pilot company and development of recommendations
4	Awareness raising on the benefits of resource efficiency, from a sustainable business perspective, and hands-on training of technical staff to identify and implement resource efficiency processes and technology improvement opportunities
5	Development and sharing of guiding material, and communication of recommendations to key stakeholders

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Abbreviations

ABR	Anaerobic Baffled Reactor
AHU	Air Handling Unit
APH	Air Pre Heater
ASEAN	Association of SouthEast Asian Nations
BEE	Bureau of Energy Efficiency
BCSDZ	Business Council for Sustainable Development Zimbabwe
BIER	Beverage Industry Environmental Roundtable
BOD	Biochemical Oxygen Demand
BOO	Build Own Operate
BOOT	Build Own Operate Transfer
Btu	British thermal unit
CD	Contract Demand
CEIA	Clean Energy Investment Accelerator
CF	Cash Flow
CFM	Cubic feet per minute
CH_4	Methane
CHP	Combined Heat and Power
CIP	Census of Industrial Production
CO_2	Carbon Dioxide
COC	Cycles of Concentration
COD	Chemical Oxygen Demand
COP	Coefficient of Performance
CRAFT	Climate Resilience and Adaption Finance & Technology Transfer facility
CSI	Cement Sustainability Initiative
CT	Cooling Tower
CTCN	Climate Technology Centre & Network
CZI	Confederation of Zimbabwe Industries
DG	Diesel Generator
DISCOM	Distribution Company
DPP	Discounted Payback Period
DSM	Demand Side Management
EBRD	European Bank for Reconstruction and Development
ECB	Energy Conservation Bond
ECM	Energy Conservation Measure
EE	Energy Efficiency
EESL	Energy Efficiency Service Limited
EHS	Environment, Health and Safety
EIB	European Investment Bank

EIM	Energy Improvement Mortgage
EMI	Equal Monthly Installment
EnMS	Energy Management System
EnPI	Energy Performance Indicator
ERH-VT	Energy Rated Homes of Vermont
ESCO	Energy Service Company
ESI	Energy Savings Insurance
EU	European Union
EV	Electric Vehicle
FAD	Free Air Delivery
FAME	Faster Adoption and Manufacture of (Hybrid and) Electric Vehicles
FCU	Fan Coil Unit
FI	Financial Institution
FY	Financial Year
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Green House Gas
GHP	Gas Heat Pump
GIZ	The Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GRI	Global Reporting Initiative
GWh	Giga-Watt hour
HAG	Hot Air Generator
HVAC	Heating, Ventilation and Air Conditioning
Hz	Hertz
IC	Internal Combustion
IE	International Efficiency
IFC	International Finance Corporation
IGBT	Insulated Gate Bipolar Transistor
IRR	Internal Rate of Return
ISO	International Organization for Standardization
IWRM	Integrated Water Resource Management
kcal	Kilo calories
kgoe	Kilogram of oil equivalent
KPI	Key Performance Indicator
kVA	Kilovolt ampere
kW	Kilo Watt
kWh	Kilowatt hour
LAN	Local Area Network
LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas

LPH	Liters per hour
LPM	Liters per minute
m	meter
m^3	Cubic meter
MAU	Make up-air unit
MBR	Membrane Bio reactor
MEPD	Ministry of Energy and Power Development
MEWC	Ministry of Environment, Water and Climate
MF	Micro Filtration
MIC	Ministry of Industry and Commerce
MJ	Mega-Joule
ML	Mega Litre
MSME	Ministry of Micro, Small and Medium Enterprises
MU	Million Units of electricity
MW	Megawatt
NASA	National Aeronautics and Space Administration
NDE	National Designated Entity
NF	Nano Filtration
NO_x	Nitrogen Oxide
NPK	Nitrogen Phosphorus Potash
NPV	Net Present Value
OEM	Original Equipment Manufacturer
OPC	Ordinary Portland Cement
PACE	Property Assessed Clean Energy
PAT	Perform Achieve Trade
PDCA	Plan-Do-Check-Act
PET	Polyethylene Terephthalate
PLC	Programmable Logic Controller
PPA	Power Purchase Agreement
PPC	Portland Pozzolana Cement
PPP	Public Private Partnership
PVC	Polyvinyl chloride
RD	Revenue decoupling
RLF	Revolving Loan Fund
rpm	Revolution per minute
RO	Reverse Osmosis
ROI	Return on Investment
SASB	Sustainability Accounting Standards Board
SAZ	Standards Association Of Zimbabwe
SCE	Specific Carbon dioxide Emission
SCM	Standard Cubic Meter
SCR	Silicon Controlled Rectifier

SDG	Sustainable Development Goal
SEC	Specific Energy Consumption
SEGR	Specific Energy Generation Ratio
SIDBI	Small Industries Development Bank of India
SME	Small and Medium Enterprise
SO_2	Sulphur Dioxide
SPC	Specific Power Consumption
SPP	Simple Payback Period
SPV	Solar Photovoltaic
SSP	Single superphosphate
SWC	Specific Water Consumption
SWH	Solar Water Heater
TA	Technical Assistance
tCO_2	tonne of carbon dioxide
tCO_2e	tonne of carbon dioxide equivalent
TDS	Total dissolved solids
toe	tonne of oil equivalent
TR	Ton of refrigeration
UASB	Up-flow Anaerobic Sludge Blanket
UF	Ultra Filtration
UJALA	Unnat Jyoti by Affordable LEDs for All
ULB	Urban Local Body
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
VCFEE	Venture Capital Fund for Energy Efficiency
VFD	Variable Frequency Drive
VRM	Vertical Roller Mill
WACC	Weighted Average Cost of Capital
WB	World Bank
WCM	Water Conservation Measure
WETT	Water Efficiency Target Tool
WHEEL	WareHouse for Energy Efficiency Loan
ZERA	Zimbabwe Energy Regulatory Authority
ZESA	Zimbabwe Electricity Supply Authority
ZETDC	Zimbabwe Electricity Transmission and Distribution Company
ZINWA	Zimbabwe National Water Authority

1 Overview of Zimbabwe's Industrial sector

1. Overview of Zimbabwe's Industrial sector

1.1. Overview of industrial sector

The industrial sector can play a key role in the overall economic development agenda as well as initiatives geared at employment creation and effective reduction in poverty[1]. Zimbabwe boasts of a diverse industrial sector characterized by a geographic spread across the country[2]. The Zimbabwe's industrial sector hit its peak in the 1990s, contributing around 16 percent to the country's gross domestic product (GDP). Industrial sector played a key role in the economy, supplying about 50 percent of its output into the agricultural sector while 63 percent of its inputs were from the agriculture sector[3]. The contribution of manufacturing sector to GDP along with annual GDP growth rate of Zimbabwe since its independence is presented in **Figure 1**[4].

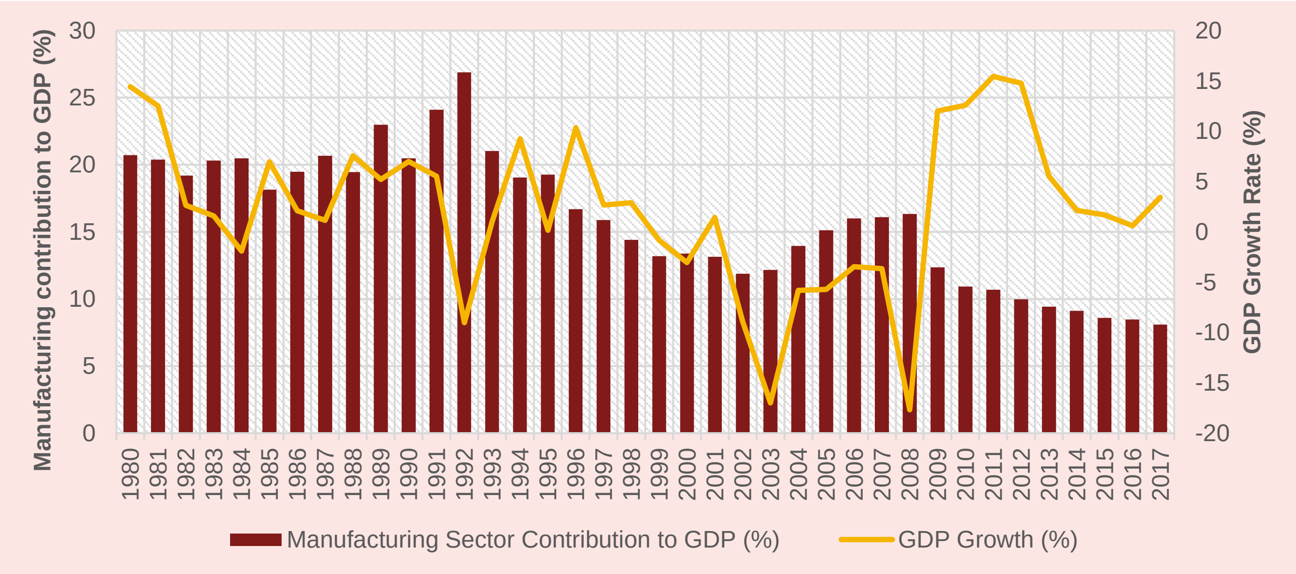


Figure 1 Manufacturing sector contribution to GDP and GDP growth rate of Zimbabwe (1980 - 2017)

1.1.1. Capacity utilization of industries

Zimbabwe's industrial sector was not spared from the effects of the economic crisis, which took place between 2000 and 2008[1]. At the beginning of the year 2009 the sector was operating at an estimated capacity utilization level of less than 10 percent, but this has since increased to 48 percent, as of 2018[5]. According to the Confederation of Zimbabwe (CZI), the two prime factors which threats to hamper efforts by industry to enhance capacity are:[5]

Foreign currency allocation	Impacts of rainfall patterns on the agricultural sector

The rise in capacity utilization in recent years can be attributed to a number of reforms including import control measures. The capacity utilization of industries in the country from 2008 to 2018 is presented in **Figure 2**.

[1] *Cornelius Dubeand and Erinah Chipumho, Response of the Manufacturing Sector to the Zimbabwe Economic Crisis, 2015*
[2] *Positioning Zimbabwe Manufacturing Sector as a Growth Driver, Zimbabwe Economic Policy Analysis and Research Unit*
[3] *Zimbabwe's manufacturing sector, https://bulawayo24.com/index-id-news-sc-national-byo-139032.html*
[4] *World Bank Database, https://data.worldbank.org/indicator*
[5] *Confederation of Zimbabwe Industries (CZI), December 2018*

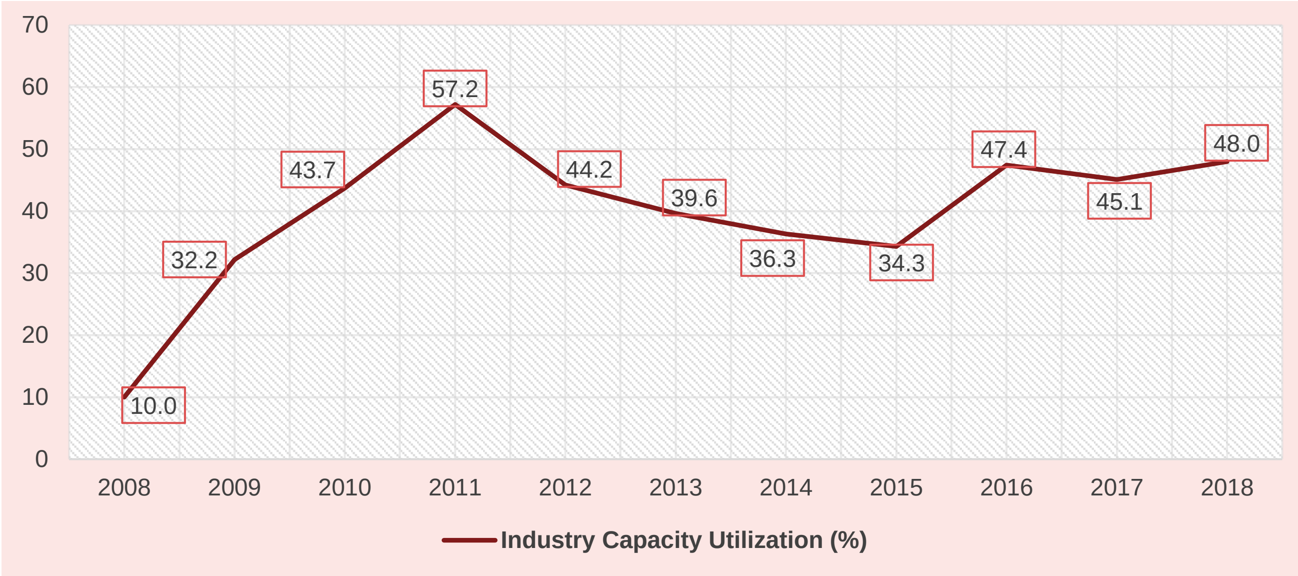


Figure 2 Industry capacity utilization of Zimbabwe (2008 - 2018)

The Census of Industrial Production (CIP) is conducted annually to obtain information on the structure and development of industry in Zimbabwe. The CIP report details about types of industries, employment, and cost of production for various sub-sector of the industrial sector. In the CIP the industrial sector is broadly classified in four major divisions[6]:

Mining & Quarrying	Manufacturing	Electricity & Water Supply	Construction
Consists of underground and surface mining and quarrying. Drilling, breaking, milling, cleaning and grading	Mechanical or chemical transformation of materials into new product. Mining and repair work excluded	Generation & distribution of electricity and Purification & distribution of water	Construction and repair of buildings, roads, bridges, sewers, railroads, dams, airports, swimming pools, communication systems

The CIP also collates information on the resource consumption including energy and water consumption as well. The data for the year 2013 was published by Zimbabwe National Statistics Agency (ZimStat) in November 2015 and is the latest information available.

1.1.2. Resource consumption in industries

The resource consumption in industries are three fold: (1) Raw material, (2) Energy - electrical & thermal, and (3) Water. The resource consumption i.e. energy and water of industrial sector in Zimbabwe based on the CIP published in 2015 is presented in following section[6].

1.1.2.1. Water consumption

The water consumption by any industrial unit is defined as the quantity of water purchased plus abstracted less sold. The unit of water consumption is cubic meters (m^3). The total water consumption of industrial sector in 2013 is 9 billion m^3[6]. Building and construction sub-sector was the major consumer of water. The sub-sector wise water consumption in Zimbabwe's manufacturing sector is shown in **Figure 3**.

[6] *Census of Industrial Production 2013, http://www.zimstat.co.zw/sites/default/files/img/publications/Production/CIP_2013_0.pdf*

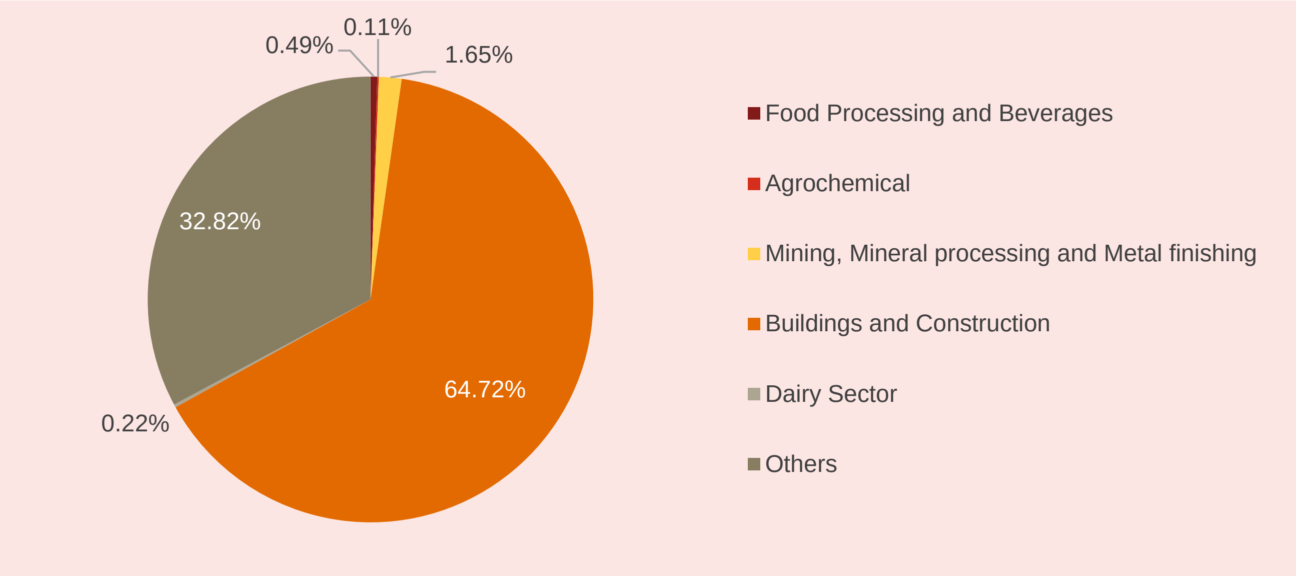


Figure 3 Sub-sector wise water consumption in Zimbabwe's manufacturing sector (2013)

1.1.2.2. Electricity consumption

The electricity consumption by any industrial unit is defined as the quantity of electricity purchased plus generated less sold. The unit of electricity consumption is kilowatt hours. The total electricity consumption of industrial sector in 2013 was 697 GWh[6], which is nearly 10% of total electrical consumption of the country. The sub-sector wise electricity consumption in Zimbabwe's manufacturing sector is presented in **Figure 4**.

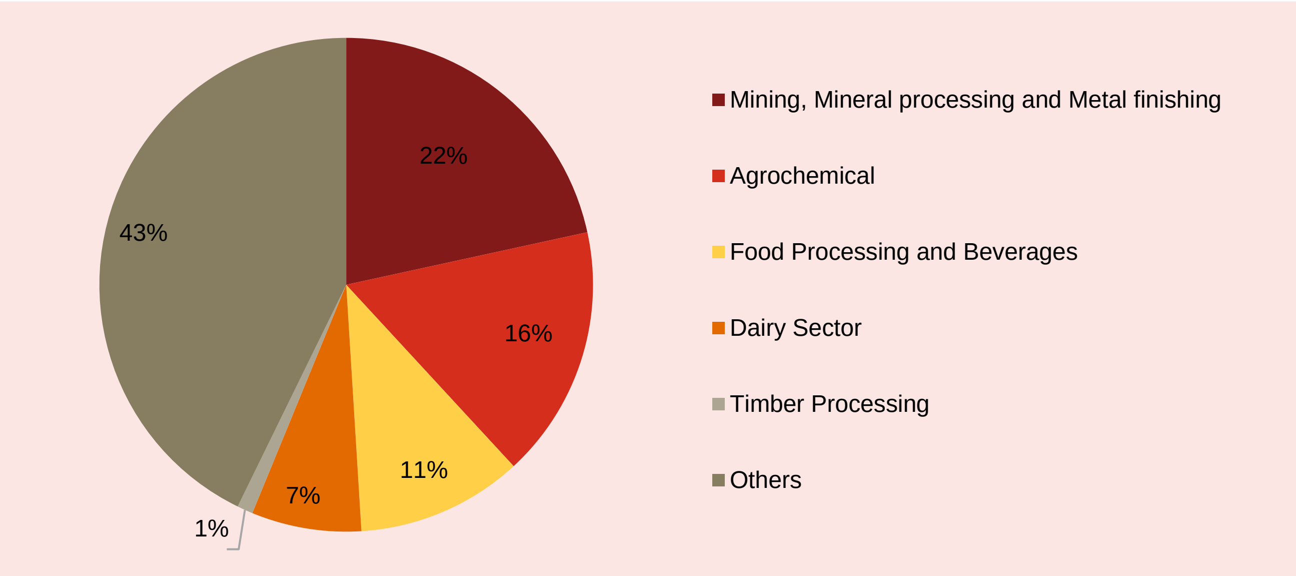


Figure 4 Sub-sector wise electricity consumption in in Zimbabwe's manufacturing sector (2013)

1.1.2.3. Thermal energy consumption

The thermal consumption of an industrial unit is the sum of the quantity of solid, gaseous and liquid fuels consumed by the industrial unit. The total thermal energy consumption of the manufacturing sector in 2013 was 9.8 trillion kcal[6]. The unit of thermal consumption is measured in kilo-calories (kcal). The sub-sector wise thermal energy consumption (combination of solid, liquid and gaseous fuels) in Zimbabwe's manufacturing sector (in billion kcal) is presented in **Figure 5**.

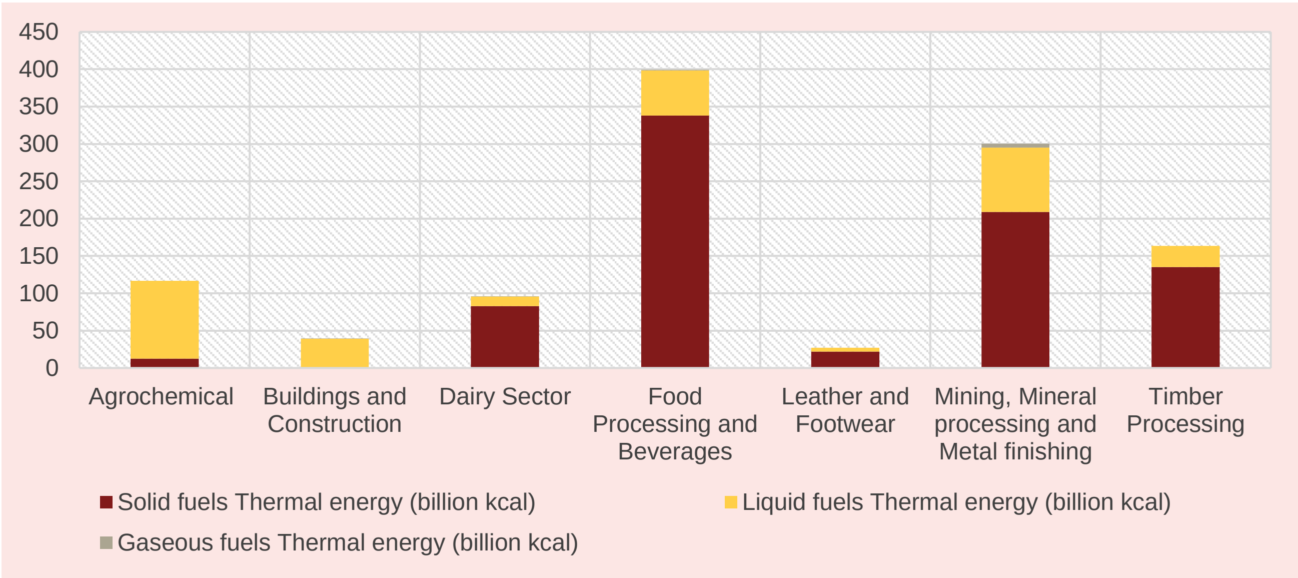
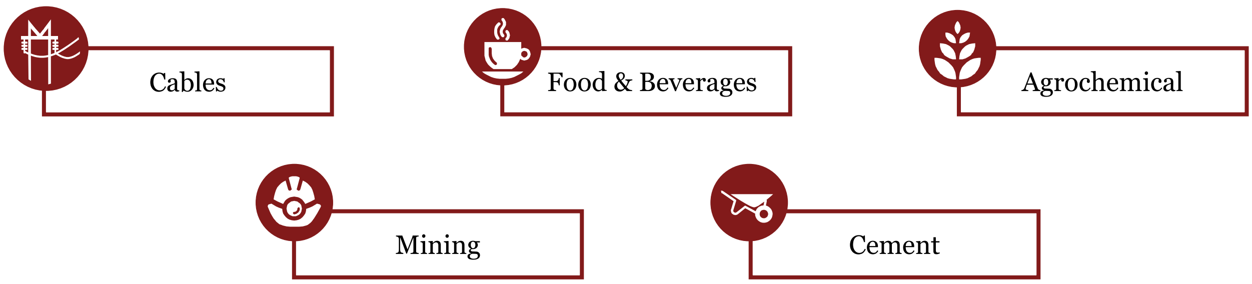


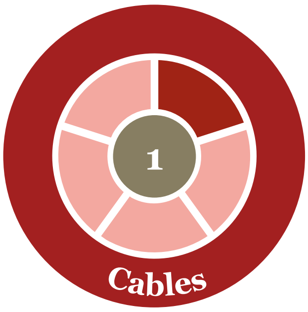
Figure 5 Sub-sector wise thermal energy consumption in in Zimbabwe's manufacturing sector (2013)

1.2. Industrial sectors covered under study

The objective of the technical assistance is to shortlist 10 demonstration industries to identify energy, water efficiency and management improvement potential. A tool was developed consisting of selection criteria to shortlist 10 companies from a longlist of applications received from various industries across Zimbabwe. The detailed shortlisting criteria is available with CTCN under project database. The unit selection questionnaire format was circulated by Business Council for Sustainable Development Zimbabwe (BCSDZ) on behalf of the project to about 80 large and small industries across Zimbabwe. 15 days' time was provided for responding the questionnaire for unit selection. Based on the criteria, 10 companies were shortlisted and they represented following five sectors.



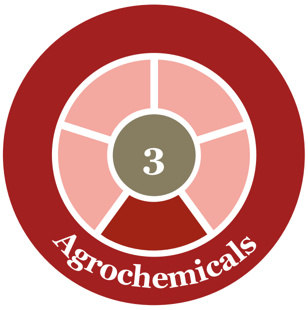
The details of each of the five sectors including typical production process and major energy and water consuming areas is presented in following section.



The cables manufacturing sector is very small in Zimbabwe. Cables manufacturers produce copper and aluminium cables mainly for transmission & distribution of electricity and cables for communication & information. The major steps of production process of copper cables are copper smelting & casting, wire drawing, bunching, bedding, armoring, sheathing, rewinding & testing and dispatch. The major steps in aluminium cables production process are wire drawing, bunching, rewinding, armoring, testing and dispatch. The major energy consuming areas are melting furnace, air compressors, water pumps, electric motors and lighting systems. The major water consuming areas are: process, ablution and domestic[7].

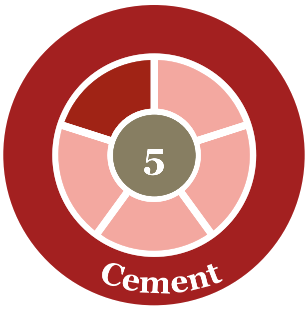
[7] *Detailed Energy and Water Audit, Conducted under the CTCN Technical Assistance project in Zimbabwe by PwC.*

The food & beverage is one of the important sub-sectors under manufacturing sector in Zimbabwe. Food & beverages sector is very vast and it consists of multiple sub-sectors such as carbonated beverages/soft drinks alcoholic beverages, sugar mill, etc. The major energy consuming areas in food & beverage sector are steam boiler, mill motors, high pressure air compressors, chiller & refrigeration system, diesel fork lifts, air compressors, air conditioners, water pumps, electric motors and lighting systems. The major water consuming areas are: water treatment - process & utility, process, ablution and domestic[7].



The agrochemical sector mainly produces fertilizers for agriculture sector. The products consists of 'Straights', 'Compounds' and 'Blends', all of which contain one or more of the three primary plant nutrients, which are Nitrogen, Phosphorus, and Potassium. The major steps of production process are raw material mixing with steam, addition of ammonia, granulation, screening, cooling, coating and storage, bagging, sewing and dispatch. The major energy consuming areas are boiler, hot air generator (HAG), air compressors, water pumps, electric motors and lighting systems. The major water consuming areas are: process, ablution and domestic[7].

Zimbabwe is a mineral rich country. It has rich varieties of minerals resources including gold, base metals (e.g. Nickel ,Copper ,Zinc and lead) and industrial minerals (limestone, Phosphates ,Clay and Dolomites) Zimbabwe has got the second largest deposits of platinum in the world. The major steps of mining process are drilling, blasting, excavation, crushing, milling, extraction and dispatch. The major energy consuming areas are electrical systems, air compressors, water pumps, electric motors and lighting systems. The major water consuming areas are: process, ablution and domestic[7].



The cement manufacturing sector is very small in Zimbabwe. Cement manufacturers produce OPC and PPC cement. The major steps of production process of cement are raw material preparation - extraction & grinding, fuel preparation - milling, clinker making & cooling, cement grinding & dispatch. The major energy consuming areas are kiln, raw mill (ball mill), coal mill (ball mill), cement mill (ball mill), material handling & transportation, air compressors, water pumps, conveying fans, electric motors and lighting systems. The major water consuming areas are: process, ablution and domestic[7].

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2 Basics of energy and water

2. Basics of energy and water

2.1. Energy basics

Energy is the ability to do work and work is the transfer of energy from one form to another. In practical terms, energy is what we use to manipulate the world around us, whether by exciting our muscles, by using electricity, or by using mechanical devices such as automobiles. Energy comes in different forms - heat (thermal), light (radiant), mechanical, electrical, chemical, and nuclear energy.

Energy efficiency is the ratio or other quantitative relationship between an output of performance, service, goods or energy, and an input of energy. E.g. Conversion efficiency; energy required/energy used; output/input; theoretical energy used to operate/energy used to operate.[8] ***Energy management*** is defined as the judicious and effective use of energy to maximize profits. Energy management assists in strategizing for adjustment and optimization of energy usage.

2.1.1. Rationale for energy efficiency in Zimbabwe

With the new technologies and alternative energy sources now available, Zimbabwe could possibly reduce its energy consumption by 50%—if there were no barriers to the implementation. But of course, there are barriers, mostly economic. Therefore, we might conclude that managing energy is not a just technical challenge, but one of how to best implement those technical changes within economic limits, and with a minimum of disruption.[9]

The rationale for energy efficiency in the country are three fold. Firstly, the vintage of technology in manufacturing sector[9]. Energy technology is changing so rapidly that state-of-the-art techniques have a half life of ten years at the most. Secondly, the economy is on a track of recovery, which implies the capacity utilization of the industries are gradually increasing, thus moving for energy efficient options can help improve the product yield. Thirdly, a reduction in energy costs to manufacture the product can be immediate and permanent[9], thus enhancing profit margins of the cash-trapped industries.

2.1.2. Energy tariff in Zimbabwe

The tariff structure energy in the country varies depending on the type of energy i.e. electricity or fuel. The fuel could be coal, diesel, petrol, etc. Electricity is supplied by Zimbabwe Electricity Transmission and Distribution Company (ZETDC). Coal is mainly supplied by CoalZim and by some of private players in the market. Diesel and petrol are generally procured from open market i.e. by Total, or Puma, or Zuva, Engen, etc. The basic tariff details of energy in Zimbabwe are presented in **Table 1**[7].

Table 1 Energy source, availability and tariff details in Zimbabwe

Sr. No.	Energy Source	Availability	Tariff details
1	Electricity	ZETDC	Connection type: Industrial / 11 kV Demand charge: US $ 5.54/kVA On peak energy charge: US $ 0.13/kWh Standard energy charge: US $ 0.07/kWh Off peak energy charge: US $ 0.04/kWh
2	Coal	Coalzim Marketing (P) Ltd	US $ 80-150 / tonne (depending on purchase quantity, coal grade and distance of transportation)
3	Diesel	Total/Zuva/Puma/Engen	US $ 1.27 /litre
4	Petrol	Total/Zuva/Puma/Engen	US $ 1.42 /litre

[8] *International Standard, ISO 50001 - Energy Management Systems - Requirements with guidance for use, 1st edition 2011-06-15*
[9] *William H. Mashburn, Effective Energy Management, 6th Edition of Energy Management Handbook*

2.2. Water basics

Water is a critically important resource, fundamental for both industrial and agricultural activity. The resource is now limited, stressed and globally 'water crises' has been ranked as the third highest risk in terms of impact due to the significant decline in quality & quantity of freshwater.[10] Global demand for water has increased six fold in the past century and is estimated to further surge by about 50% by 2030. Given this surge, next 15 years could see a shortfall in the supply as compared to the demand thereby posing a serious threat to the achievement of the Sustainable Development Goals (SDGs) and the specific SDG goal 6 on clean water and sanitation.[11]

2.2.1. Rationale for water efficiency in Zimbabwe

Zimbabwe has limited groundwater resources since the greater part of the country consists of rocky terrain where the potential for groundwater is low. The country relies mainly on surface water resources with the available renewable freshwater sources estimated to be around 12.3 billion m^3 (2014) and per capita water availability estimated to be 796 m^3 (2014).[12] Having said this, the country falls well below the global average of 1,700 m^3 for per capita water availability thereby indicating the water scarcity level of the country.[13] Agriculture, industry and domestic-use constitute 82%, 6% and 12% of the annual freshwater withdrawals respectively.[14] Adding to this, erratic climatic conditions and droughts are pushing the country to become more vulnerable to the impacts of climate change by creating a scenario of low agriculture yields and food insecurity.

Although agriculture is the primary sector in the country, climate change impacts are posing greater repercussions for the industrial sector as well. In the recent past, low water levels in hydroelectric dams have led to increase power shortages. For instance, during the 2014-16 drought, Kariba dam, which both Zimbabwe and Zambia rely heavily on for electricity, only had sufficient water to supply electricity for six months.[15]

With the Government calling for sustainable management for water as part of the national development agenda, strong emphasis has been laid to improve water quality and expand equitable access across all regions and sectors. Built on the principles of harnessing, conserving, protecting and managing water, the National Water Policy is one such framework that aims to improve security and availability of water to all multi-purpose users.

2.2.2. Water tariff in Zimbabwe

The tariff structure in the country is under the purview of the lead government agency, the Zimbabwe National Water Authority (ZINWA). The prices are consciously structured in a manner to promote access to water by all citizens and users. The prices are structured in a way that balances the two competing interests of affordability and availability through sustainable pricing that allows continuous production and supply of the water to users. As per the Zimbabwean Government Gazette of 2016, the tariffs for raw water are presented in **Table 2**[16].

Table 2 Water tariff based on customer category in Zimbabwe

Customer category	Tariff US $ / Mega Litre (ML)
A2 Farmers	5.00
A1 Farmers	3.00
Communal Farmers	2.00
Industry	9.45
Commercial Agriculture (Estates)	12.00
Mining	50.00

[10] *World Economic Forum, The Global Risks Report 2018*
[11] *EPA Research, A National Roadmap for Water Stewardship in Industry and Agriculture in Ireland*
[12] *World Bank Development Indicators, 2017*
[13] *According to the Falkenmark Water Stress Indicator, a per capita availability of less than 1,700 cubic metres (m^3) is termed as a water-stressed condition, while if per capita availability falls below 1000 m^3, it is termed as a water scarcity condition*
[14] *World Bank Development Indicators, 2017*
[15] *USAID Zimbabwe, Country Development Cooperation Strategy 2016-2021*
[16] *Zimbabwe Gazette 2016, http://extwprlegs1.fao.org/docs/pdf/zim170798.pdf*

2.2.3. Guiding principles for water efficiency

The process of water efficiency centers on the concept of water stewardship and consideration of the principles of integrated water resource management (IWRM). Water efficiency involves identifying & measuring the different uses of water, understanding the risks associated with various source & disposal pathways, and managing water efficiently to maximize economic, environment & social well-being attributed to the resource. Water efficiency is an iterative process and needs to be developed throughout the lifecycle of operations.

2.2.3.1. Water stewardship

Water stewardship is a key principle that underpins good practice in water management. The Alliance of Water Stewardship defines it as *'the use of water that is socially equitable, environmentally sustainable and economically beneficial, achieved through a stakeholder-inclusive process…'* concept is built on four aspects:[17]

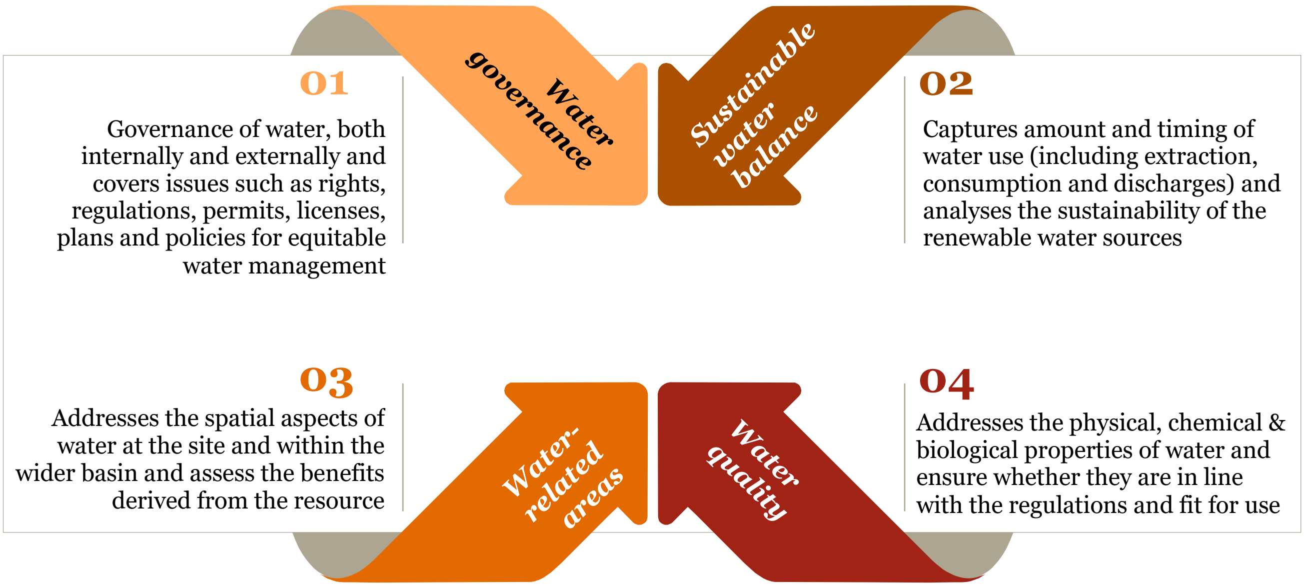


Figure 6 Water stewardship aspects

2.2.3.2. Integrated Water Resources Management

In line with the previously mentioned principles, IWRM promotes coordinated development and management of water, land and related resources (e.g. energy consumption, GHG emissions) with the ulterior objective of improving economic and social well-being while protecting the environment. One of the key principles outlined by IWRM is that water is a shared resource and its uses are interdependent. While assessing any water resource for use in an operation, the following aspect are to be considered

- Impact of water use on other users
- Impact of other users on the operation
- Importance in terms of biodiversity and ecosystem services

The purpose of this manual is to demarcate the rationale for water efficiency in Zimbabwe and specifically for the industrial sector alongside presenting detailed overview on water efficiency indicators, data management for water consumption monitoring, water management technologies and leading operating practices for uplifting the current water management practice of the various industrial sectors.

[17] *IPIECA, Efficiency in water use, 2014*

2.3. Detailed audit methodology

2.3.1. Audit and its purpose

The energy and water audit is important step in effective management and use of the resources. An energy and water audit is defined as *the verification, monitoring and analysis of use of energy and water including submission of technical report containing recommendations for improving Energy Efficiency and Water Efficiency with cost benefit analysis and an action plan to reduce energy and water consumption*[18]. The purpose of an energy and water audit is presented in **Figure 7**. In the figure "energy and water" is represented as "resource".

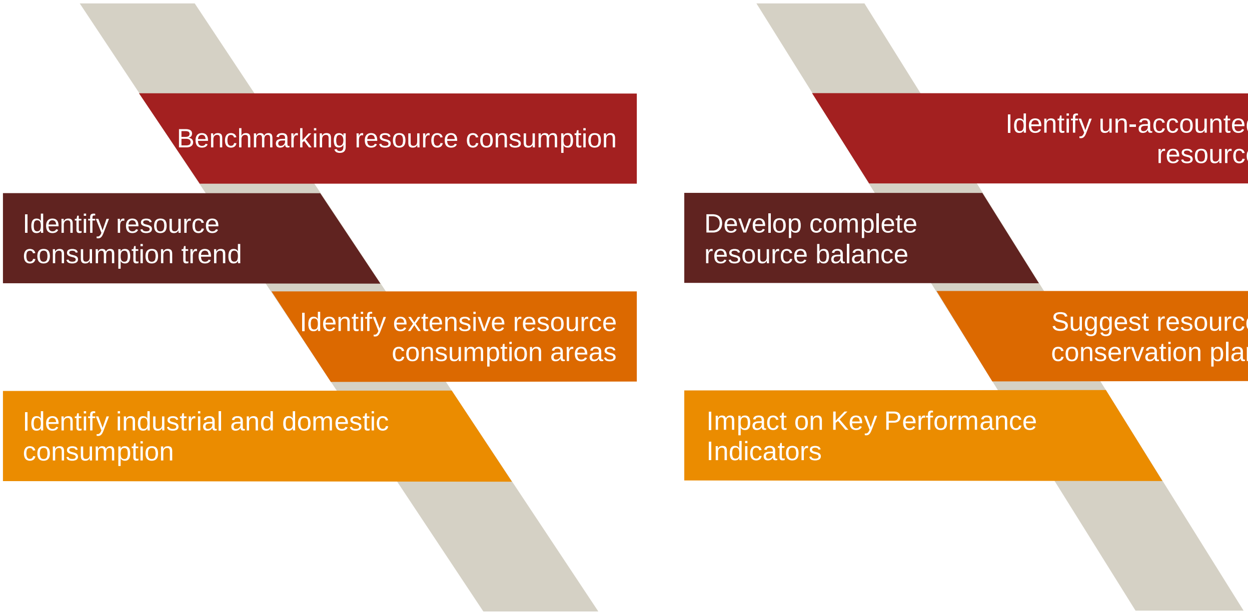


Figure 7 Purpose of energy and water audit

The audit can be classified in four major categories depending on purpose and depth of the audit. These are: walk through audit, detailed audit, focused audit and investment grade audit. Brief detail of the types of audit are presented in **Table 3**.

Table 3 Types of audit

Type of audit	Brief Description
Walk through audit	Walk-through or preliminary audit is the simplest & quickest method for conducting audit in a facility. It typically includes demarcation of various sections of facility, identification and prioritisation of major resource consuming sections, brief description of probable resource conservation measures.
Focused audit	Focused Energy audit is a special type of audit. It focuses on one particular section or a sub-process of the organization depending on the requirement of the organization. For example, an organization might want to focus audit of only boiler or steam system.
Detailed audit[19]	Detailed energy audit includes a complete description of the facility, including an equipment inventory, an energy balance, detailed energy savings and costs associated with each low-cost and not-cost measure, financial analysis of each recommended measure, identification and rough estimates of capital project

[18] *Energy Conservation Act 2001 - Ministry of Power, Government of India*
[19] *Detailed Energy Audit, http://www.ensaveindia.com/DetailedEnergy.aspx*

Type of audit	Brief Description
	costs and savings. Energy savings and economic feasibility are determined as accurately as possible. The reports contain more detailed descriptions of the measures.
Investment grade audit	Investment grade audit is a detailed energy audit with detailed financial analysis of cost benefit including NPV, IRR and ROI. The investment grade audit proposes action plan for implementation and baseline details for monitoring and verification.

2.3.2. Audit methodology

The steps in the audit execution will include establishment of baseline, performance assessment of equipment, estimation of operating specific energy consumption/operating efficiency, specific water consumption and identifying energy and water conservation measures. The methodology for the audit depicting various tasks, activities and outcomes is presented in **Figure 8**.

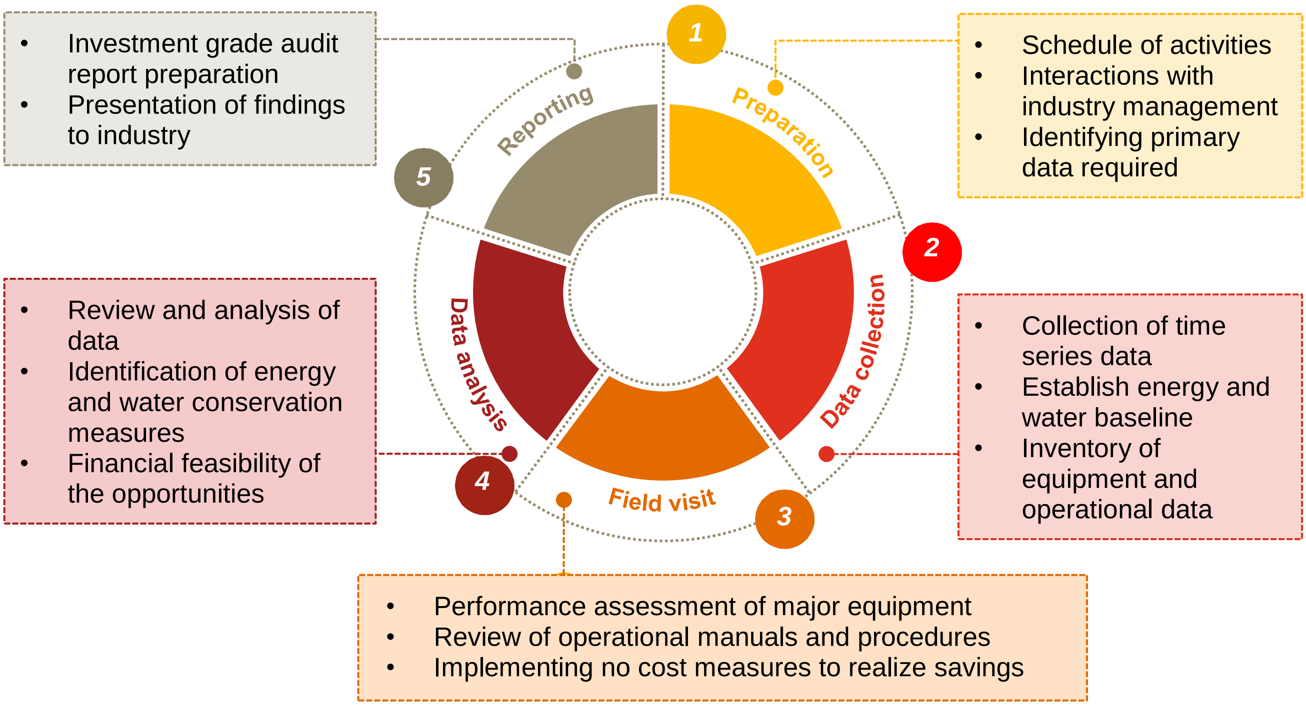


Figure 8 Energy and water audit methodology

2.3.2.1. STEP 1: Initial preparatory work & inception meeting

This step is one of the most important step during the execution of the assignment as it sets the blueprint for all downstream activities, including the overall footprint, pace of activities, availability of existing information, etc. The project team organizes an inception meeting with management representative from industry and various head of departments. Discussions points during the inception meeting:

- Detailed methodology for conducting detailed energy and water audit of each company
- Strategy for executing the assignment
- Field movement plans for the proposed team
- Appointment of nodal officer (s) for each identified industry
- Availability of historical time series data
- Assistance required from company officials during the audit

The audit team will assimilate key discussion points and then initiate its field activities through visiting industries as per mutually agreed field movement plan.

Data collection *is very important* ***to know the historical trend*** *of electricity, fuel and water consumption in the plants as well as collection of data required* ***for estimation of EnPIs and energy & water saving potential***

2.3.2.2. STEP 2: Collection and analysis of time series data

The audit team circulates a data collection questionnaire for water and energy audit to the industry. The questionnaire consists of (a) Basic information about the plant facility like production process, (b) Resource profile of the plant set-up: Historical energy and water data - monthly as well yearly, key sub-process/ equipment, (c) Major resource consuming equipment: installed equipment inventory (design), its operating parameters such as operating hours, actual load and any operational restrictions. Maintenance plans and procedures, and (d) Process flow and boundaries of the plant (see **Figure 9**). The questionnaire has provisions for the industry to provide any other relevant information, if necessary.

A quiestionnaire is extremely important to understand the level of resource efficiency in the industry.

A filled questionnaire would serve as the foundation for conducting audit.

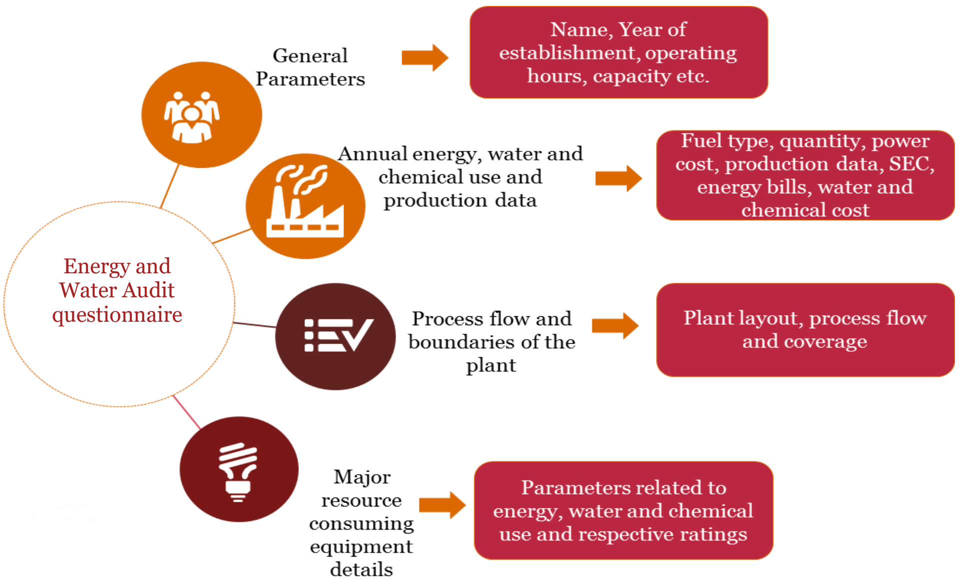


Figure 9 Components of audit questionnaire

The audit team analyses questionnaire data to establish energy and water consumption baselines of the industry as whole and important sub-processes/equipment. These baselines will be depicted in form of energy and water performance indicators (EnPIs/Water KPIs) and these EnPIs & KPIs are compared industry benchmarks within country and internationally. These will enable the team in identification of thrust areas where significant potential for energy and water conservation exists. The project team provides guidance to the industry representative to fill the questionnaire. If gaps exists, they are filled during the field visit by project team for detailed measurement and performance assessment.

System Boundaries

Each industry is unique in itself. In order to appropriately arrive at energy and water performance indicators (EnPIs) for a particular industry, it is of prime importance to properly define the system boundaries. The project team defines the system boundaries for the industry. The detailed field study is carried out for equipment and process falling within these boundaries. Depiction of types of boundaries with indicative examples is presented in **Figure 10**.

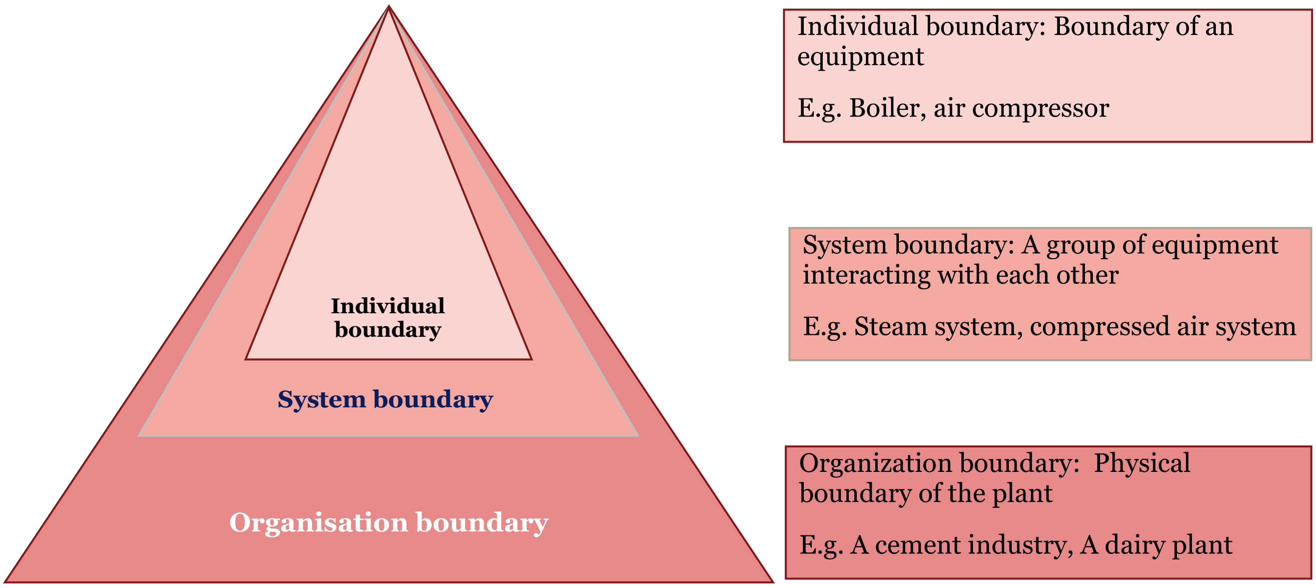


Figure 10 System boundaries

2.3.2.3. STEP 3: Field visit

The audit team consists of experts on energy (thermal and electrical), water and renewables. The team visits the site as per the field movement plan for conducting comprehensive audit. While carrying out the audit, the team will follow the readily available industrial standards (wherever applicable). The detailed tasks that will be covered under the audit of the plants are covered in following section.

Initial meeting/personnel interview with company officials

On the 1st day of visit, the project team organizes meeting with the industry officials to appraise them about the activities which will be carried out during the field measurements and discuss work plan, identify measurement points/sites, assistance required from them during the measurements and data collection. This task is a very important step in executing audit smoothly and in the time bound manner. The meeting would help to determine number of systems, sections and equipment to be covered under study, their past electricity, steam and water consumption record and measures adopted in recent past to reduce energy and water consumption. This will help identify a ***Management Representative***, with whom the project team interacts during the course of field measurements. The project team thereafter takes a walk-through of the industry to know exact locations, energy and water consuming equipment and plan arrangements for the measurements schedule.

Field study and measurements

The audit team scrutinizes the filled-in questionnaire. In case the plant/unit officials don't possess any important data/facts regarding electricity, fuel, natural gas and water consumption of the plant equipment. The project team would submit a detailed list of the area/ equipment which would be audited along with the visit schedule. The project team would visit the different sections of the respective companies to take measurements of various operating parameters of different energy and water consuming equipment. The audit team uses state-of-the art energy/water audit portable instrument kit for undertaking measurements. Typical list of the audit instruments is presented in **Figure 11**.

Methodology for renewable energy assessment

The potential assessment for solar resource will be carried out using secondary data from 'Surface meteorology and Solar Energy' a renewable energy resource web site powered by National Aeronautics and Space Administration (NASA). Based on availability of potential, suitability of technology options such as solar water heater (SWH), solar roof-top photovoltaic (SPV) and biogas will be assessed.

Flue gas Analyzer

Water flow meter

S - Type pitot tube

3 - Phase power analyzer

Digital Manometer

Temperature logger

Digital pressure gauge

Anemometer

High temperature thermocouples

Figure 11 Energy and water audit instruments

The renewable resource availability and its potential for utilization can be estimated based on data collated in the format presented in **Table 4**.

Table 4 Renewable energy resource and potential assessment

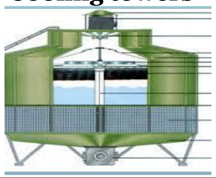
Solar rooftop potential assessment:		
Total roof area	m^2	
Roof slope (approximately)	degree	
Average roof shaded	% or m^2	
Roof construction (Concrete, metal sheets, polycarbonate, etc.)		
Latitude and longitude of plant location	degree	
Elevation	m	
Daily solar radiation (average, maximum, minimum)	$kWh/m^2/day$	
Biomass potential assessment:		
Is there any biomass as by-product of process	Yes / No	
Plant location/process area		
Type of biomass (Woody, non-woody, waste, any other)		
Quantity generated, tonne per month		
Is biomass utilised for energy generation	Yes / No	
If YES what is the type of usage?		
Quantum of energy generated		

Areas and equipment to be covered under the Energy & Water Audit

The detailed methodology to be adopted for carrying out field measurement and the study of above mentioned equipment is presented in **Table 5.**

Table 5 Equipment-wise audit methodology

S. No.	Name of equipment	Measurements to be conducted	Instruments	Key Performance Indicators (EnPIs)	Remarks
1	**Boiler** 	Flue gas analysis Flow measurements • Feed, Make up, Condensate water • Steam Temperature measurement • Flue gas, Fuel, Steam • Make up, Feed water, Condensate return Pressure measurement • Steam, Fuel, Combustion air Electrical parameters • Pumps, Fans	• Flue gas analyser • Ultrasonic water flow meter • Digital temperature indicator • Pressure gauge • Thermal imager • Three phase power analyser	• Boiler efficiency - % • Evaporation ratio	• Depends on loading of the boiler • Historical data of one year to be provided by plant
2	**Thermic fluid heater** 	• Flue gas analysis • Fuel input quantity • Thermic fluid inlet and out temperature • Pumps and fans power	• Flue gas analyser • Digital temperature indicator • Thermal imager	• Thermal efficiency - %	• Depends on loading of the THF • Historical data of one year to be provided by plant
3	**Chiller** 	• Chilled water flow rate • Chilled water inlet temperature • Chilled water outlet temperature • Compressor power • Indoor air temperature and RH • Condenser exhaust air temperature • Condenser exhaust air relative humidity	• Ultrasonic water flow meter • Three phase power analyser • Anemometer • Digital temperature indicator	• Coefficient of Performance COP • Specific Power Consumption – kW/TR	• Depends on season and usage

S. No.	Name of equipment	Measurements to be conducted	Instruments	Key Performance Indicators (EnPIs)	Remarks
4	**Electric furnace** 	• Measurement of all electrical parameters • Temperature measurement	• Three phase power analyser • Pyrometer	• Specific Energy Consumption – kWh/product	• Study will cover 2-3 batch • Historical data of one year to be provided by plant
5	**Aux. transformer** 	• Measurement of all electrical parameters	• Three phase power analyser	• Efficiency - % • Loading - %	• Data logging for 24 hours
6	**Air Compressors** 	• FAD test • Demand test • Leakage test	• Anemometer • Three phase power analyser • Digital temperature indicator	• Specific Power Consumption – kW/cfm • Leakage - %	• Plant have to insure the shutdown of the plant and machinery during the leakage test
7	**Pumps** 	• Water flow rate • Suction pressure • Discharge Pressure • Input Power	• Pressure gauge • Ultrasonic water flow meter • Three phase power analyser	• Efficiency - %	• Pumps associated with induction furnace
8	**Cooling towers** 	• Input Temperature (Water Side) • Output temperature (Air and Water Side) • Air Flow Rate • Water flow rate • Power input to the Fan	• Digital Temperature loggers • Ultrasonic water flow meter • Three phase power analyser • Anemometer	• Effectiveness - %	• CT associated with induction furnace

S. No.	Name of equipment	Measurements to be conducted	Instruments	Key Performance Indicators (EnPIs)	Remarks
9	**Fans and blowers** 	• Electrical parameters • Air flow rate • Differential pressure	• Three phase power analyser • Anemometer • Pitot tube	• Efficiency - %	• Fans associated with CT in (5)
10	**Electrical motors** 	• Measurement of all electrical parameters	• Three phase power analyser • Stroboscope • Thermal imager	• Efficiency -% • Loading - %	• All operating motors associated with (3), (4), (5) and (6)
11	**Lighting** 	• Lux Level • Power Input	• Lux Meter • Single phase power analyser	• Luminous efficacy – lux/W	• As per the standards provided by authorities
12	**Diesel generator set** 	• Fuel consumption • Electricity generation	• Three phase power analyser	• Specific Energy Generation Ratio – kWh/L • Loading - %	• Depends on operation of the DG set

2.3.2.4. STEP 4: Data analysis and measures for improvement

At the end of the field measurements, the audit team will discuss the initial findings and possible energy and water savings opportunities with the concerned officials of the respective companies. The project team will carry-out a detailed review and analysis of the time series data collected and actual measurements conducted to arrive at performance assessment of equipment and systems. The water and energy performance indicators (EnPIs) will be established for all the sub-process and entire plant. Based on above steps energy and water conservation opportunities will be identified. The identified opportunities will be grouped as ‘No cost’, ‘Low cost’ and ‘Capital intensive measures’ for plant (**Figure 12**).

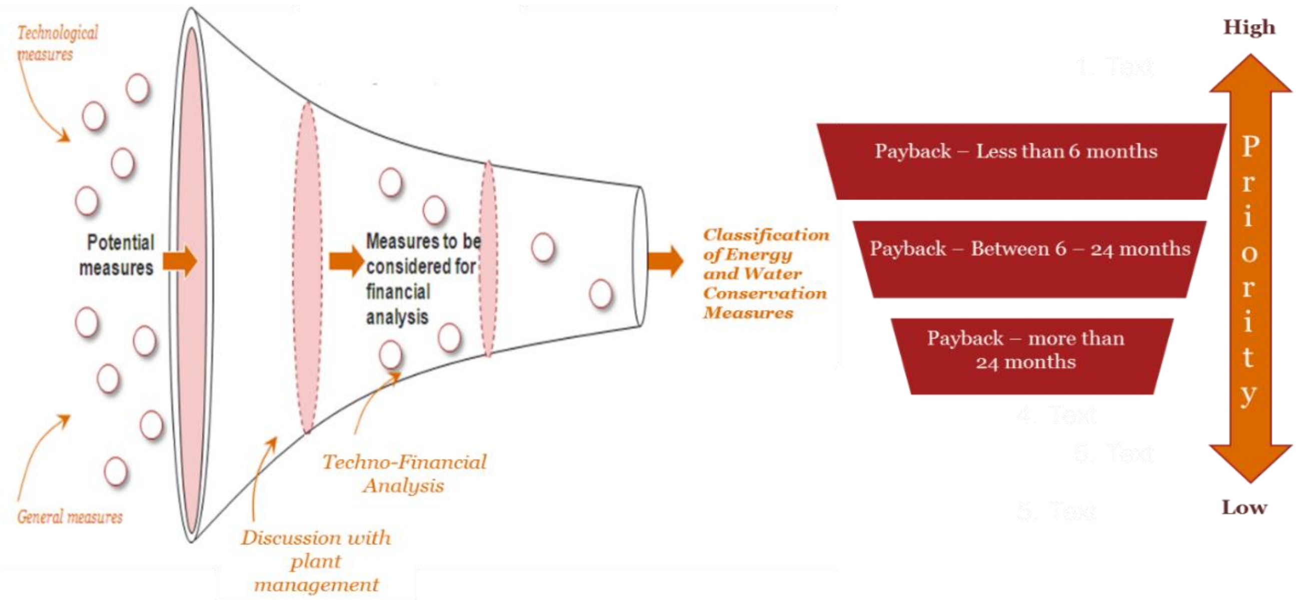


Figure 12 Classification of energy and water conservation measures

Throughout steps 1 – 4 the project team will interact with the plant staff i.e. management, area/section representative, etc. The team will discuss the following:

- Preliminary findings and recommendations
- EnPIs in compliance with ISO 50001
- Benchmarking plants EnPIs against sector’s
- Views and comments on implementation of no and low cost recommendations

During the field study, wherever possible the project team tries to implement the no cost measures to realize the energy and water savings by the plant immediately.

Tools

The audit team makes use of its in-house *Microsoft Excel based tools* (**Figure 13**) to assess performance of the equipment and systems. The team makes use of proven tools for identification of EnPIs and performance assessment such as *material balance* and *energy balance* (**Figure 13**). The project team has vast experience is utilizing the tools for energy and water efficiency improvement in different industrial sectors.

Apart from this, there is a significant number of tools and information sources accessible online through several platforms and tools. The team identifies suitable tools for the assignment depending on the equipment and process studied. The team makes use of open source software tools such as RETScreen, PVsyst, etc. for renewable energy potential assessment. The team also looks for case studies and opportunities for saving energy and water by referring to online tools such as Energy Star.

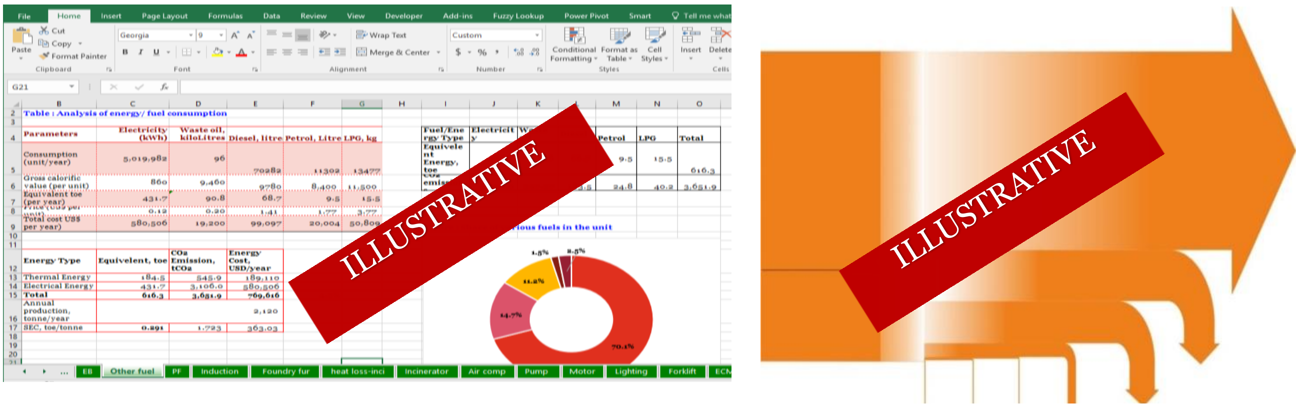


Figure 13 Audit tools illustration

2.3.2.5. STEP 5: Report preparation and presentation

After carrying out detailed analysis on the energy and water conservation opportunities and the team will have discussion with plant management. The project team will prepare a draft energy and water audit report. The audit report will also provide recommendations for energy saving options along with financial viability options. An illustrative example of the contents of the audit report is shown in **Figure 14**:

- Table of contents
- Executive summary
- Company overview, process description
- Energy and water baseline of the plant
- Energy and water performance indicators
- Performance assessment of key equipment and areas/sections in the plant
- Observations and findings of the study
- Comprehensive benefit / cost analysis
- Payback period calculation
- Low/no cost energy and water conservation opportunities
- List of instruments and devices used during audit with accuracy level and traceability of calibration status

Table of Contents

Figure 14 Table of contents of audit report: Illustrative

The audit team would submit the draft audit reports to respective companies and have discussions followed by presentation on draft report to each selected company. The project team would present the audit analysis and finalized energy and water conservation opportunities before the company officials.

3 Key Performance Indicators

3. Key Performance Indicators

Key Performance Indicator (KPI) can be defined as a quantifiable/measurable value that demonstrates how effectively the industry or equipment or process is performing. KPIs can be financial and non-financial. The energy and water KPIs are mainly non-financial but have financial implications. The energy and water KPIs can be equipment level, departmental and/or overall industry level KPIs. The characteristics of KPIs are presented in **Figure 15**.

Figure 15 Characteristics of KPIs

The four challenges in defining and maintaining KPIs are: (a) understanding industry's strategy and key objectives, (b) measure is deemed important to area/process of the industry, (c) targets of KPI improvement must be realistic and (d) in case, accurately measuring and reporting indicators is difficult, internal process or SOP should be defined.[20]

The energy and water KPIs are detailed separately in the following sections.

3.1. Energy Performance Indicators (EnPIs)

The Key Performance Indicators with reference to energy are defined in the International Standards ISO 50001 Energy Management Systems as Energy Performance Indicators (EnPIs). The EnPIs and its related terms are also well defined in the international standard document on ISO 50001. Important and select terms along with definitions and key notes are presented in **Table 6**[8].

Table 6 EnPIs related terms and definitions

Term	Definition	Notes
Energy baseline	Quantitative reference(s) providing a basis for comparison of energy performance	An energy baseline reflects a specified period of time
Energy consumption	Quantity of energy consumed	-
Energy efficiency	Ratio or other quantitative relationship between an output of performance, service, goods or energy, and an input of energy	Conversion efficiency; energy required/energy used; output/input; theoretical energy used to operate/energy used to operate
Energy performance	Measurable results related to energy efficiency, energy use and energy consumption	Results can be measured against organization's energy targets and energy performance requirements
Energy performance indicator	Quantitative value or measure of energy performance, as defined by the organization	EnPIs could be expressed as a simple metric, ratio or a more complex model

EnPIs can be a simple parameter, a simple ratio or a complex model. Examples of EnPIs can include energy consumption per time, energy consumption per unit of production, and multi-variable models. The organization can choose EnPIs that inform the energy performance of their operation and can update the EnPIs when business activities or baselines change that affect the relevance of the EnPI, as applicable[8].

[20] *The Basics of Key Performance Indicators, https://www.thebalancecareers.com/key-performance-indicators-2275156*

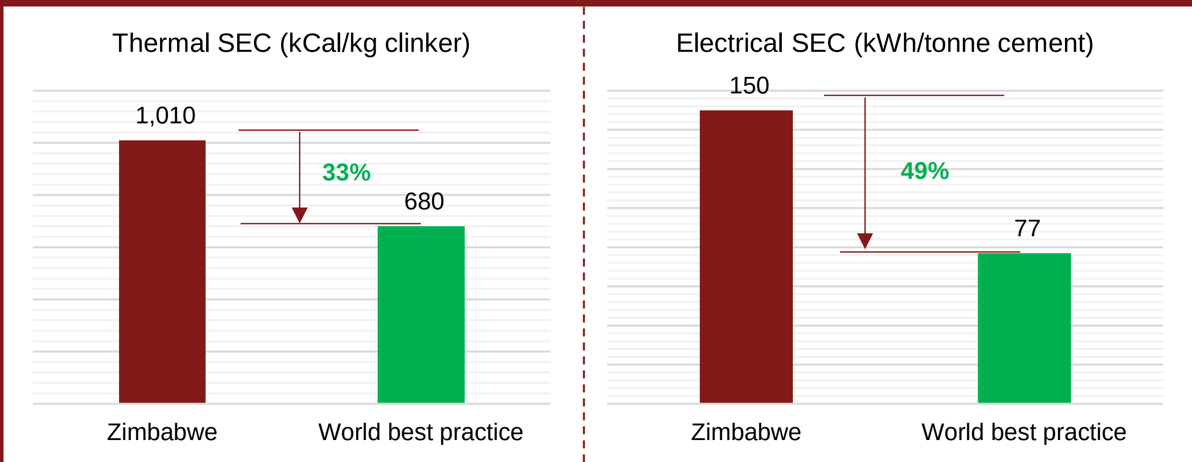
3.1.1. EnPIs for industrial sectors

The indicative EnPIs the various industry sectors are listed in **Table 7**. These indicator values are provided for comparative purposes only and organizations can utilize these to establish a robust internal benchmarking plan that can lead to continuous improvements. The energy performance indicator for cement sector in Zimbabwe with reference to world benchmark is showcased in **BOX 1**.

Table 7 Energy Benchmark of Industry sectors

Sector	Unit	Value	Reference
Cement	kWh/tonne cement kcal/kg clinker	65 - 150 650 - 1300	- Bureau of Energy Efficiency, Government of India - International Efficiency Technology Database
Sugar	kWh/tonne cane crushed	15 - 75	- Widening the coverage of PAT Scheme India - International Renewable Energy Agency
Mining Opencast	MJ/tonne of ore	97 - 256	- Benchmarking Energy Efficiency of Opencast Mining, Advances in Energy Research IIT Bombay
Fertilizer	GCal/tonne urea GCal/tonne NH_3	3.7 - 7.9 6.9 - 8.6	- Bureau of Energy Efficiency, Government of India - Fertilizer industry and energy use: Dutch Energy Intensive Industry
Beverages	MJ/L	0.56	- Schweppes Holding Africa Sustainability Report 2017
Iron & Steel	toe/tonne product	0.46 - 0.53	- GIZ Outcome evaluation study PAT cycle-1, Bureau of Energy Efficiency, Government of India
Textile	toe/tonne product	0.75 - 0.90	- GIZ Outcome evaluation study PAT cycle-1, Bureau of Energy Efficiency, Government of India

BOX 1: Cement sector energy performance indicator - Zimbabwe v/s World Best Practice[7]
Source: PwC Analysis



The United Nations Industrial Development Organization (UNIDO) benchmarked the energy efficiency potential for 26 industrial sub-sectors in 2010 by looking at sector specific indicators of performance in terms of energy per unit of output (UNIDO 2010). The study broke down the results in developing and developed countries and also presented figures for the global average, the lowest found in the sample, and the achievable performance using Best Available Technology (BAT). The findings are comparable to those of the IEA, with an average savings potential of 26% of industrial energy usage. They are summarized in Table 4.[21]

[21] *UNIDO Benchmark of Industrial sub-sectors, 2010*

Table 8 Selected industry energy benchmark data

Sector	Unit	Developed countries	Developing countries	Global average	BAT
Petroleum refineries	EEI	0.7 – 0.8	1.3 – 3.8	1.25	1.0
High value chemicals	GJ/t	12.6 – 18.3	17.1 – 18.3	16.9	10.6
Ammonia	GJ/t	33.2 – 36.2	35.9 – 46.5	41.0	23.5
Methanol	GJ/t	33.7 – 35.8	33.6 – 40.2	35.1	28.8
Alumina production	GJ/t	10.9 – 15.5	10.5 – 24.5	16.0	7.4
Aluminum smelting	MWh/t	14.8 – 15.8	14.6 – 15.0	15.5	13.4
Copper	GJ/t	–	–	13.8	6.3
Zinc	GJ/t	15.2 – 19.7	16.7 – 37.2	23.6	–
Iron and steel	EEI	1.2 – 1.4	1.4 – 2.2	1.5	1.0
Clinker	GJ/t	3.3 – 4.2	3.1 – 6.2	3.5	2.9
Cement	kWh/t	109 – 134	92 – 121	109	56
Lime	GJ/t	3.6 – 13.0	5.0 – 13.0	–	–
Glass	GJ/t	4.0 – 10.0	6.8 – 7.8	6.5	3.4
Brick making	MJ/kg	1.5 – 3.0	0.8 – 11.0	–	–
Tiles	GJ/t	1.9 – 7.3	3.1 – 8.3	–	–
Sanitaryware	GJ/t	4.2 – 11.3	4.4 – 20.0	–	–
Pulp and paper	EEI	0.9 – 1.7	0.4 – 2.3	1.3	1.0
Textile spinning	GJ/t	3.5 – 3.6	3.5 – 3.6	–	–
Textile weaving	GJ/t	11.0 – 65.0	5.0 – 43.0	–	–
Brewery	MJ/hl	–	–	229	–
Cheese	GJ/t	4.3 – 35.2	–	–	–
Fluid milk	GJ/t	3.1 – 6.5	–	–	–

3.1.2. Equipment specific EnPIs

The performance indicator of any industry can be further bifurcated into specific EnPIs of sub-process and equipment. The performance of individual equipment can be assessed by investigating the equipment specific EnPI. For example the energy performance indicator of a Foundry is represented as energy consumed per tonne of casting produced (kWh/tonne), the indicator can be further divided to arrive at equipment-wise EnPI such as electric induction melting furnace (kWh/tonne), air compressor (kW/cfm). The EnPI for any equipment varies depending on end application, usage pattern and a number variable parameters. The major equipment used in industries along with performance indicator, its unit and typical range is presented in **Table 9**.

Table 9 EnPIs of various equipment used in industries[22]

Equipment	EnPI	Unit	Value
Air compressor - Screw	Specific Power Consumption	kW/cfm	0.16 - 0.24
Air compressor - Reciprocating	Specific Power Consumption	kW/cfm	0.18 - 0.27
Air conditioner - Split	Energy Efficiency Ratio	W cooling/W power	1.80 - 4.50
Air conditioner - Window	Energy Efficiency Ratio	W cooling/W power	1.80 - 3.50
Boiler - Fossil fuel	Evaporation ratio	t steam/t fuel	5 - 13
	Efficiency	%	50 - 80
Boiler - Biomass	Evaporation ratio	t steam/t fuel	3 - 10

[22] *Select equipment only, not a comprehensive list. The EnPI range is indicative from best to worst*

Equipment	EnPI	Unit	Value
	Efficiency	%	35 - 75
Chiller - Air Cooled	Specific Power Consumption	kW/TR	0.86 - 1.80
Chiller - Water Cooled	Specific Power Consumption	kW/TR	0.66 - 1.50
Cogeneration - Sugar	Specific Electricity Generation	kWh/tonne cane	55 - 80
Cooling tower	Effectiveness	%	35 - 75
Diesel generator	Specific Energy Generation Ratio	kWh/L	2.0 - 3.8
Fan - Centrifugal	Static efficiency	%	58 - 83
Fan - Axial	Static efficiency	%	45 - 85
Forging furnace - Steel	Specific Energy Consumption	kg LPG/tonne	80 - 130
Heat exchanger - Gas to gas	Effectiveness	%	30 - 70
Heat exchanger - Liquid to liquid	Effectiveness	%	60 - 90
Hot Air Generator	Efficiency	%	20 -70
Induction furnace - Melting	Specific Energy Consumption	kWh/tonne	530 - 1350
Lighting - Incandescent	Luminous Efficacy	lm/W	15 - 20
Lighting - Mercury vapour	Luminous Efficacy	lm/W	30 - 65
Lighting - CFL	Luminous Efficacy	lm/W	45 - 65
Lighting - LED	Luminous Efficacy	lm/W	90 - 130
Lighting - Induction	Luminous Efficacy	lm/W	80 - 110
Motor (IE3) ≤ 7.5 kW	Efficiency	%	80 - 90
Motor (IE3) > 7.5 kW	Efficiency	%	>90
Pump - Head > 60m	Efficiency	%	25 - 55
Pump - Head ≤ 60m	Efficiency	%	40 - 80
Refrigeration above zero temperature	Specific Power Consumption	kW/TR	0.69 - 1.41
Refrigeration subzero temperature	Specific Power Consumption	kW/TR	1.25 - 2.50
Reheating furnace - Walking beam	Specific Energy Consumption	SCM gas/tonne billet	40 - 75
Reheating furnace - Pusher hearth	Specific Energy Consumption	SCM gas/tonne billet	26 - 36
Thermic Fluid Heater	Efficiency	%	50 - 88
Transformer	Efficiency	%	98.0 - 99.5
	Loading	%	30 - 50

3.2. Water Key Performance Indicators

Through a comprehensive understanding of its water use, an organization can assess the impacts it has on water resources that benefit the ecosystem, and the organization itself. KPIs are defined to measure the effectiveness of a reduction program over time and act as standard reference points that provide valuable insight into a program's performance. Initially, there may only few KPIs that focus on basic water streams. As the water management program matures, KPIs evolve or new KPIs may be created to encourage continuous improvement.

Over the years, several standards have been formulated globally for industries to report and monitor their water performance. Few of them include **International Finance Corporation (IFC) Environment, Health and Safety Guidelines, Global Reporting Initiative (GRI) Standards, Sustainability Accounting**

Standards Board (SASB) Sector Standards, Beverage Industry Environmental Roundtable (BIER) Benchmarks, CDP Water Security Disclosures, CEO Water Mandate and Brewers Association Sustainability Manual. This section of the manual presents an overview of the indicative KPIs and benchmarks, which are most relevant for the various industries covered under the water audit.

3.2.1. Water efficiency KPIs

The indicative KPIs the various industries are presented in **Table 10**. These indicator values are provided for comparative purposes only and organizations can utilize these to establish a robust internal benchmarking plan that can lead to continuous improvements.

Table 10 Water benchmark industry sectors

KPI	Unit	Value	Reference standard
Industry: Cement			
Non-batching fresh water use (Baseline)	L/m^3	64.4	Sustainable Concrete Plant Guidelines
Batching fresh water use (Baseline)	L/m^3	124.0	Sustainable Concrete Plant Guidelines
Industry: Beverages[23]			
Water use ratio (Breweries)	L/L	3.53	BIER Benchmarking Study 2016
Water use ratio (Bottling including soft drinks and bottled water)	L/L	1.96	BIER Benchmarking Study 2016
Industry: Fertilizer			
Water consumption for Single Superphosphate (SSP) production	m^3 water/ton of SSP	0.1-2	IFC EHS Guidelines for Phosphate Fertilizer Manufacturing
Water consumption for Phosphoric acid production	m^3 cooling water / ton of P_2O_5	100-150	IFC EHS Guidelines for Phosphate Fertilizer Manufacturing
Water consumption for NPK production through nitro-phosphate process	m^3 cooling water / ton of NPK	17	IFC EHS Guidelines for Phosphate Fertilizer Manufacturing
Industry: Sugar			
Water consumption per unit of cane production	m^3 /ton of cane	0.5–0.9	IFC EHS Guidelines for Sugar Manufacturing
Water consumption per unit of beet production	m^3 /ton of beet	0.5	IFC EHS Guidelines for Sugar Manufacturing

3.2.2. Leading performance monitoring parameters

Over and above the indicators previously mentioned organizations should also establish internal performance monitoring protocols in line with leading international standards and practices. These standards have been formulated and adopted globally by leading industries to disclose their performance to stakeholders, both internal and external. Some of the KPIs that could be monitored by the industries are presented in **Table 11**.

[23] Benchmarks published by BIER includes analysis of data provided by 19 companies, representing nearly 1,500 facilities across six continents

Table 11 Water KPIs, its unit and reference standard

KPI	Unit	Reference Standard
Water withdrawal (by source) - Surface water - Groundwater - Harvested rainwater (collected and used) - Quarry water, for cement plants and mines (collected and used) - Sea water - Waste water - Municipal water	m^3/year	• Cement Sustainability Initiative (CSI), Guidance on Good practices for water accounting • GRI Standards • SASB Sector Supplements
Water use (by destination) - Process water - Non-recycled water for mechanical cooling - Potable water (drinking, cleaning and toilet) - Losses / Leakages - Water for irrigation	m^3/year	• Cement Sustainability Initiative (CSI), Guidance on Good practices for water accounting • GRI Standards • SASB Sector Supplements
Water discharge (by destination) - Surface water (river, lake) - Groundwater (subsurface / well) - Off-site water treatment - Ocean or sea water - Other beneficiaries	m^3/year	• Cement Sustainability Initiative (CSI), Guidance on Good practices for water accounting • GRI Standards • SASB Sector Supplements
Water consumption per product	L/tonne product	• Cement Sustainability Initiative (CSI), Guidance on Good practices for water accounting • GRI Standards • Brewers Association, Water and Wastewater: Treatment/Volume Reduction Manual

To compile this information, the organizations can use the following approach:

a. Determine which facilities are located in areas with water stress
b. For each of these facilities, monitor and document the total water consumption

For an indicative example of how to present this information, refer section 4 of this manual (*Data management and analysis – Energy and Water Monitoring).*

4 Data management and analysis

4. Data monitoring and analysis

Data consists of the basic structure for which information is created. ***Management*** is the orchestration of processes intended to carry out a task[24]. ***Data Management*** is the process of proactively reviewing and evaluating the data and its quality to ensure that it is fit for purpose[25]. ***Data analysis*** is a process of inspecting, cleansing, transforming, and modeling data with the goal of discovering useful information, informing conclusions, and supporting decision-making[26]. Data monitoring saves the organization time and money that would otherwise be spent to check and transform data before it is moved. Data monitoring promotes business agility because new initiatives involving data can be undertaken immediately without a time-consuming data preparation phase[27]. ***Metering of data*** is a technique used to monitor and collect certain data over a specified period of time. Data metering can be manual or automatic. ***Smart meters*** typically records consumption data and communicates the information to user either via. Local area network (LAN) or wirelessly. Data monitoring and analysis plays a crucial role and establishing the EnPIs/KPIs and achieving targets of improvement.

Energy i.e. electricity, fuels and water are important resources, in the following sections their analysis, management and interpretation is presented.

4.1. Analysis of energy consumption

4.1.1. Energy monitoring and data collection

Energy monitoring and targeting is primarily a management technique that uses energy information as a basis to eliminate waste, reduce and control current level of energy use and improve the existing operating procedures. It builds on the principle "you can't manage what you don't measure". It essentially combines the principles of energy use and statistics. The essential elements of monitoring and targeting system are presented in **Table 12**[28].

Table 12 Elements of monitoring and targeting

Parameter	Description
Recording	Measuring and recording energy consumption
Analyzing	Correlating energy consumption to a measured output, such as production quantity
Comparing	Comparing energy consumption to an appropriate standard or benchmark
Setting targets	Setting targets to reduce or control energy consumption
Monitoring	Comparing energy consumption to the set target on a regular basis
Reporting	Reporting the results including any variances from the targets which have been set
Controlling	Implementing management measures to correct any variances, which may have occurred
Checking	Accuracy of energy invoices
Allocating	Energy costs to specific departments
Determining	Energy performance/efficiency
Recording	Energy use, so that projects intended to improve energy efficiency can be checked
Highlighting	Performance problems in equipment or systems

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[24] *What is Data Management? - Definition & Tools, Katherine Wenger, PhD, https://study.com*
[25] *Data Monitoring, https://www.edq.com/glossary/data-monitoring/*
[26] *Xia, B. S., & Gong, P. (2015). Review of business intelligence through data analysis. Benchmarking, 21(2), 300-311*
[27] *What is Data Monitoring? https://www.informatica.com/in/services-and-training/glossary-of-terms/data-monitoring-definition.html#fbid=66ipsJLg18w*
[28] *Energy monitoring and targeting, Guide Book 1, Bureau of Energy Efficiency*

4.1.2. Electricity consumption data analysis

4.1.2.1. Electricity billing

The actual tariffs that the customer pay depends on the consumption of the electricity. The consumer bill varies according to their requirements. The industrial consumers pay more tariffs because they use more power for long times than the domestic consumers. The electricity tariff has a number of components[29]. The components and its explanation is provided in **Table 13**.

Table 13 Electricity billing components

Parameter	Unit	Description
Contract demand	kVA	Amount of power a customer agrees to pay to have available at all times
Maximum demand	kVA	Highest level of electrical demand monitored in a particular period
Demand charge	US $	Charge for maintaining constant supply of electricity
Power factor		Ratio of the real power that is used to do work and apparent power
Electricity consumption	kWh	Total electrical energy consumed in a month
Time of day	kWh	Tariff structure in which different rates are applicable for use of electricity at different time of the day
Energy charge	US $	Charge on consumption of electrical energy
Rebate / Penalty	%	Rebate or penalty could be on power factor, demand more than contract demand, late payment, etc.
Fuel escalation charge		Considered when only the contract price is affected, upward or downward by certain pre-established percentage
Electricity duty		The duty is charged on consumption at the applicable rate per unit of electricity consumed
Total monthly amount	US $	Total monthly charge on electricity consumption including all charges and applicable duty & tax

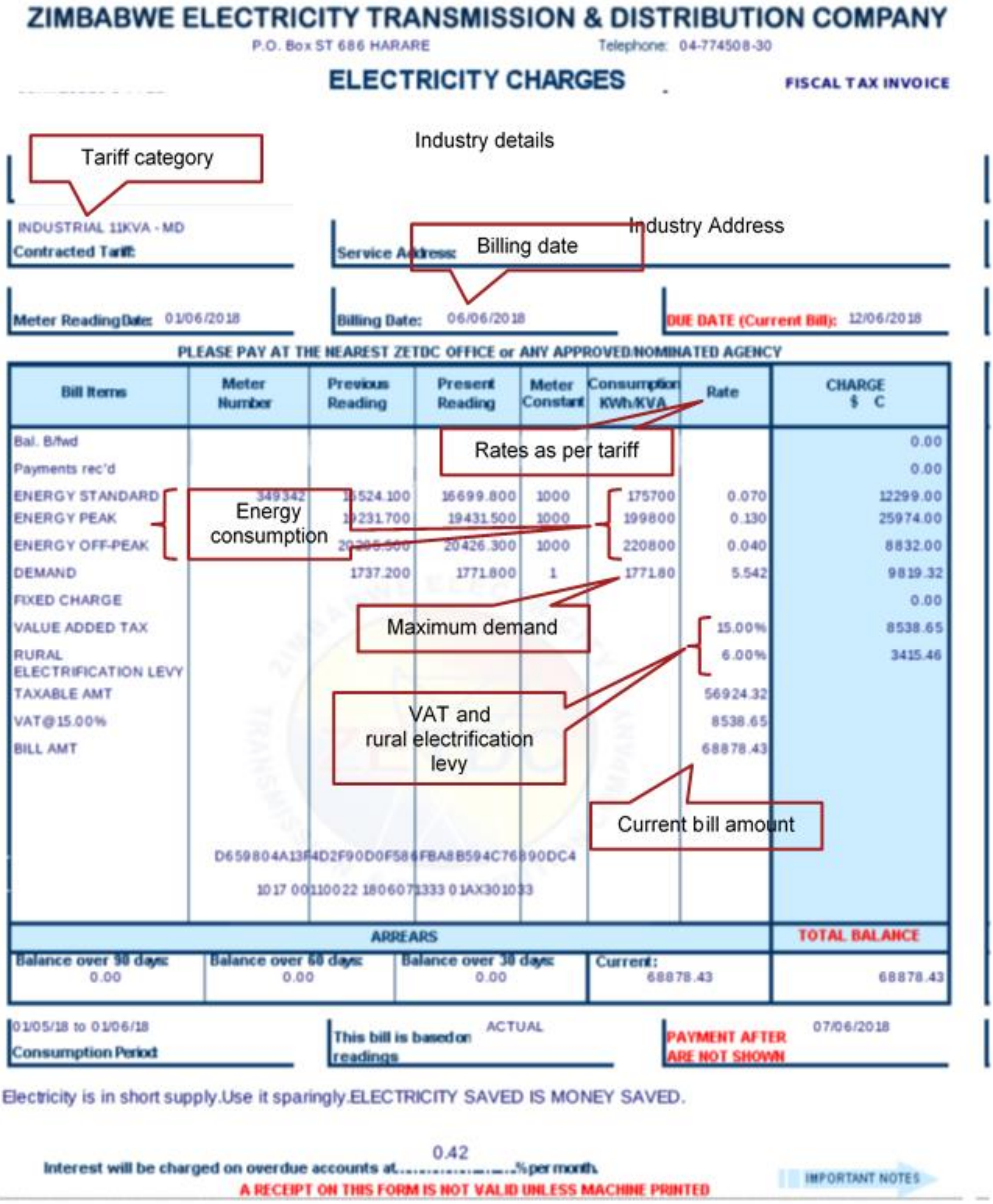
The Zimbabwe Electricity Distribution Company's (ZETDC) is responsible for distribution and retail of electricity to the final end user[30]. The present electricity tariff in Zimbabwe is effective from 1st September 2014 as notified by Zimbabwe Energy Regulatory Authority (ZERA). The tariff categorized for domestic, public lighting, agricultural, industrial and institutional. The tariff structure for the industries in Zimbabwe are "*Mining, Industrial, Commercial & Pumping work customers- Maximum demand*". The electricity tariff for industry includes monthly demand charge, interruptible demand charge, and on-peak, standard, off-peak energy charge. The details of industrial tariff category is presented in **Table 14**[31].

Table 14 Industrial electricity tariff in Zimbabwe

Parameter	Unit	LV supply	11 kV supply	33 kV supply	Secondary distribution
Fixed monthly charge	US $	0.00	0.00	0.00	0.00
Monthly capacity charge	US $/kVA	NA	5.54	4.07	2.60
Interruptible demand charge	US $/kVA	NA*	NA	NA	1.95
On-peak energy charge	US $/kWh	NA	0.13	0.13	0.13
Standard energy charge	US $/kWh	0.12	0.07	0.07	0.07
Off-peak energy charge	US $/kWh	NA	0.04	0.04	0.04

** Not Applicable*

[29] *Electricity Tariff, https://circuitglobe.com/electricity-tariffs.html*
[30] *ZETDC, https://zetdc.co.zw/about-us/*
[31] *ZERA, https://www.zera.co.zw/images/ZETDC_Tariff_Schedule.pdf*



ZIMBABWE ELECTRICITY TRANSMISSION & DISTRIBUTION COMPANY

P.O. Box ST 686 HARARE Telephone: 04-774508-30

ELECTRICITY CHARGES **FISCAL TAX INVOICE**

Contracted Tariff: INDUSTRIAL 11KVA - MD

Service Address:

Meter Reading Date: 01/06/2018 Billing Date: 06/06/2018 DUE DATE (Current Bill): 12/06/2018

PLEASE PAY AT THE NEAREST ZETDC OFFICE or ANY APPROVED/NOMINATED AGENCY

Bill Items	Meter Number	Previous Reading	Present Reading	Meter Constant	Consumption KWh/KVA	Rate	CHARGE $ C
Bal. B/fwd							0.00
Payments rec'd							0.00
ENERGY STANDARD	349342	15524.100	16699.800	1000	175700	0.070	12299.00
ENERGY PEAK		19231.700	19431.500	1000	199800	0.130	25974.00
ENERGY OFF-PEAK		20205.500	20426.300	1000	220800	0.040	8832.00
DEMAND		1737.200	1771.800	1	1771.80	5.542	9819.32
FIXED CHARGE							0.00
VALUE ADDED TAX						15.00%	8538.65
RURAL ELECTRIFICATION LEVY						6.00%	3415.46
TAXABLE AMT						56924.32	
VAT@15.00%						8538.65	
BILL AMT						68878.43	

D659804A13F4D2F90D0F586FBA8B594C76B90DC4

1017 00110022 1806071333 01AX301033

ARREARS				TOTAL BALANCE
Balance over 90 days: 0.00	Balance over 60 days: 0.00	Balance over 30 days: 0.00	Current: 68878.43	68878.43

Consumption Period: 01/05/18 to 01/06/18 This bill is based on readings: ACTUAL PAYMENT AFTER 07/06/2018 ARE NOT SHOWN

Electricity is in short supply.Use it sparingly.ELECTRICITY SAVED IS MONEY SAVED.

Interest will be charged on overdue accounts at 0.42 % per month.

A RECEIPT ON THIS FORM IS NOT VALID UNLESS MACHINE PRINTED

IMPORTANT NOTES

Industry details such as address, account number, etc.

CHEQUES SHOULD BE MADE PAYABLE TO ZIMBABWE ELECTRICITY TRANSMISSION AND DISTRIBUTION COMPANY AND CROSSED

4.1.2.2. Electricity bill analysis

The electricity bill analysis consists of understanding concepts of the electricity bill (explained in previous section) and review of energy consumption profile. Three most important parameters to be analysed are electricity consumption profile, maximum demand v/s contract demand and power factor profile. Sample analysis of the three parameters is presented below.

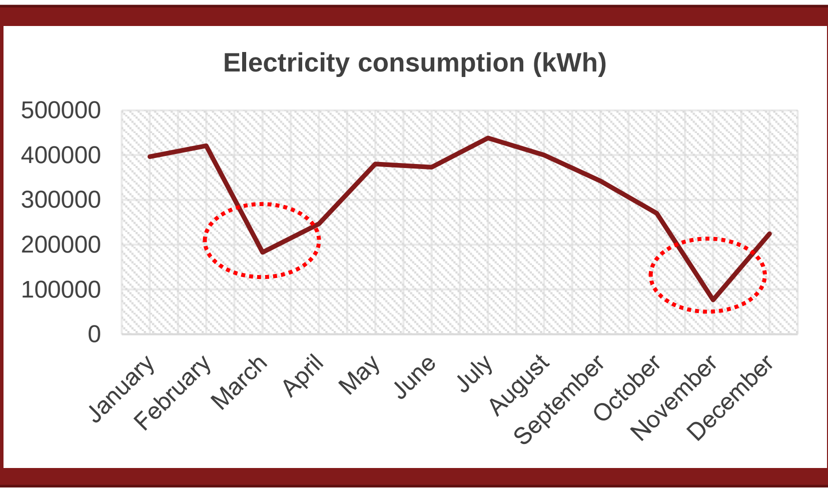


Illustration of monthly electricity consumption profile and variation in consumption.

It clearly shows the production in month of March and November was quite low

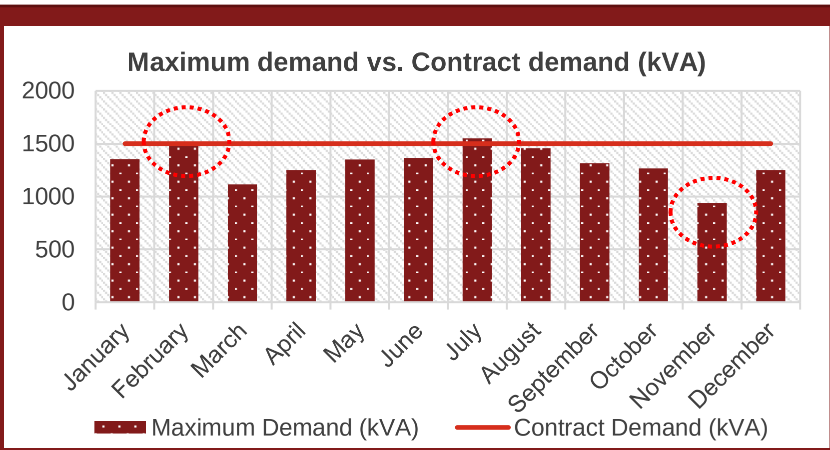


Illustration of monthly maximum demand vs. contract demand.

It can be seen in February & July the maximum demand has shot beyond contract demand whereas in November its less than 75% of CD

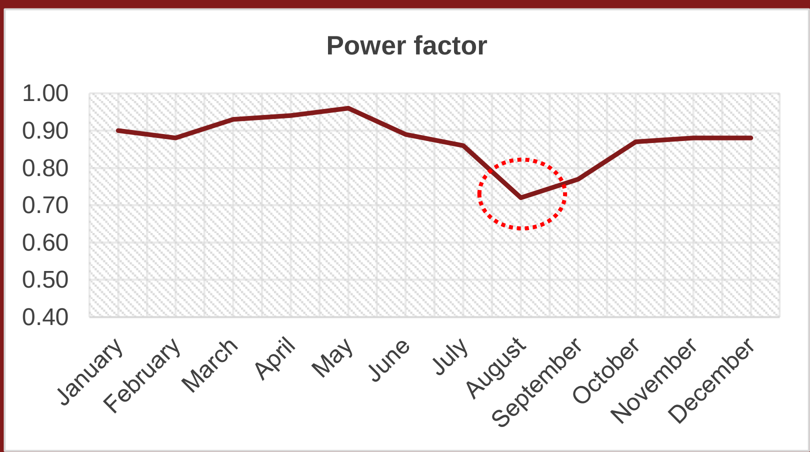


Illustration of monthly power factor of the industry.

The average power factor is 0.87. A good power factor is above 0.95 (ideally unity)

4.1.3. Fuels consumption data analysis

The prominent fuels used in industries include coal, diesel, petrol, liquefied petroleum gas (LPG), waste oil and biomass such as bagasse. The analysis of fuel consumption is twofold firstly analyzing the consumption pattern of individual fuels and secondly consumption of total thermal energy consumption. Overall energy consumption is the sum of electricity and fuels consumption (see below). It is quite important to convert all the fuels to single unit in order to add them. The conversion table for various energy forms is presented in **Table 15**.

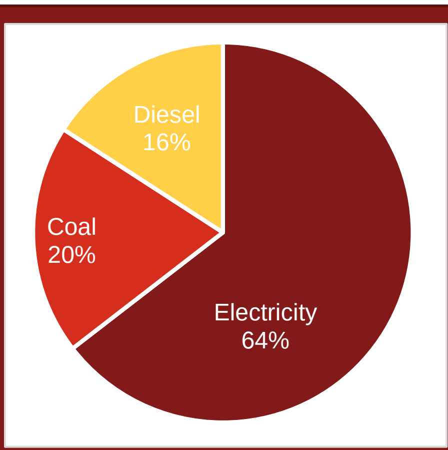
Table 15 Conversion table

Energy form	Conversion factor
1 kWh electricity	860 kcal
1 Liter diesel	9,780 kcal
1 kg LPG	11,500 kcal
1 Liter waste oil	9,460 kcal
1 kg coal	7,270 kcal

	Electricity	Coal	Diesel
Consumption	4,045,975 kWh	145,250 kg	87,479 L
Conversion	860	7270	9780
Energy	347.95385	105.59675	85.55446

Case of a typical industry using electricity, coal, and diesel as fuel. Electricity powers all equipment. Coal is used in boiler and diesel is used in internal material transport (fork-lifts) and diesel generator.

Consumption of each type of energy is converted to single unit and represented in form of a pie chart



4.2. Analysis of water consumption

4.2.1. Water monitoring and data collection

4.2.1.1. Water monitoring

Monitoring water use is the periodical collection of information on the total water drawn from all sources for any use during a given period. This is an integral part of any management system and enables the organization to understand water use patterns and identify potential inefficiencies. Monitoring also plays an essential role in setting reduction targets for water use and efficiency. Building on the previously mentioned KPIs, this section presents an overview of data management system, including establishing a data collection system, process for ensuring accuracy of data and guidelines for setting actionable goals and objectives.

4.2.1.2. Data collection

Data management often goes beyond collecting usage and cost data from a monthly utility invoice. It includes identifying process areas, support functions, and facility operations that have the prospects for improvement. Prior to beginning data monitoring process, an organization should essentially create an inventory of all water using activities / facility. **Table 16** presents an example of inventorization of water use in a cement plant[32].

[32] *Cement Sustainability Initiative (CSI), Guidance on Good practices for water accounting*

Table 16 Inventorization of water use for a cement plant

Area	Water use location
Cement production	- Slurry for wet process or granulation - Cooling mechanical equipment (such as cement coolers) - Cooling of materials (e.g. injection into clinker cooler) - Exhaust gas conditioning - Emission controls (flame cooling, de-NO_x, SO_2 scrubber) - Waste heat recovery systems - Dust control by watering roads, materials and stockpiles - Support and ancillary operations such as office buildings, general services, maintenance workshops and garages - Irrigation for greening and rehabilitation within facility boundaries - Domestic use - Leakage and loss
Aggregate	- Wet screening - Aggregates washing
Ready Mix Concrete	- Concrete production - Mixer & equipment washing - Ready-mix truck washing

Post identification of the sources, the typical strategies deployed for tracking water use include monitoring usage through water bills and meters[33].

Water bills

Wherever possible, use water invoices or receipts from utilities to determine the organization's water use. Collecting data for the past three to five years can effectively help the company determine the baseline usage information from which one can start determining overall usage patterns.

Meters

Installing meters and sub-meters at key locations is an ideal way to quantify and segregate water usage. However, it is an organization's decision to install measurement devices on water withdrawal, water discharge and the major consumption points. Meters offer the most accurate and reliable way to guage water, and ensure continuous flow records and may be equipped with many options, such as data loggers and telemetry that relay real-time data. It is important to choose a suitable water meter based on[34]:

- Water quality
- Range of flow
- Consistency of flow or turbulence
- Availability of power
- Ease of access
- Cost

There are several leading practices for metering water use data, including choosing the appropriate locations for meters and sub-meters; selecting, installing and maintaining meters; and reading and recording metered data to track water use and integrating it into the organization's water management plan.

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33 *US Department of Energy, Best Management Practice: Water Management Planning*
34 *Cement Sustainability Initiative (CSI), Guidance on Good practices for water accounting*

Choosing what to meter and sub-meter

It is ideal to meter all water received by the facility, regardless of source. For example, even if the facility's water is solely supplied by an alternative source (e.g. municipality supplied treated water), a source meter can still be installed to track and manage water use. If multiple sources of water are provided to a facility, each source should be metered and tracked separately. Facility owners and operators should consider installing separate sub-meters to measure specific end uses that are permanently plumbed, as indicated in **Table 17**[35].

Table 17 Recommended practice for water sub-metering

Sub-meter location*	Recommended practice
Cooling towers	- Meter cooling tower make-up water and blowdown water supply lines - A single make-up meter and a single blowdown meter can record flows for multiple cooling towers if they are controlled with the same system - Cooling towers that are separately controlled should have separate make-up and blowdown water meters
HVAC systems	- Individually or collectively meter HVAC systems with aggregate annual water use of 100,000 gallons or more or if the facility has 50,000 square feet or more of conditioned space - Metered systems should include evaporative coolers, humidifiers, mist cooling devices, and recirculating water systems with a fill water connection, such as chilled water, hot water, and dual temperature systems
Steam boilers	- Meter the make-up water supply line to steam boilers with a rating of 500,000 British thermal units per hour (Btu/h) or greater - A single make-up meter can record flows for multiple boilers
Irrigation	- Meter irrigation systems that are automatically controlled
Industrial processes	- Individually meter industrial processes consuming more than 1,000 gallons per day on average
Alternative water sources	- Meter water use from sources such as gray water, rainwater, air handler or boiler condensate, or other sources

**The list of end uses specified are indicative and may vary across different industries*

Other monitoring techniques

If sub-metering is not possible across all end-uses, organizations can estimate water usage with methods like:

- Measuring flow rates using buckets and stop watch
- Estimating volume of daily use from toilets and faucets
- Determining the capacity and load factor of the cooling tower
- Measuring the irrigation area to determine water needs
- Calculating water use of equipment per cycle and cycles of operation

[35] *US EPA, WaterSense at Work: Best Management Practices for Commercial and Institutional Facilities*

4.2.1.3. Ensuring data accuracy

After identification and quantification of data for water usage, the information should be reviewed for accuracy. The absence of reliable data will create hurdles while tracking progress. The rationale for reliable initial data is important for monitoring new waste use sources, review progress against KPIs and identify cost savings. To verify the data, an organization can consider addressing the following key questions:

Q1	Does the volume of water used appear reasonable based on the quantity of product produced?
Q2	Is the volume of water used consistent with historical data (e.g., last month and same time last year)?
Q3	Is there any missing data that should be included in the inventory (e.g., water from new wastewater treatment facility, water from quarries etc.)?

Post verification, the information should be shared with the management. Organizations that have collected information for several years can consider reporting progress against water use efficiency KPIs and overall cost savings. It is always recommended for transparent communication of the current scenario and the ulterior goals and targets that the organization is aiming to achieve.

4.2.1.4. Data reporting

The following templates provide an example of how to present information at the organization level and facility level and more specifically for industries operating in water stress areas. Organizations can amend the template according to its practices, by including additional necessary information. The sample template for water data reporting is presented in **Table 18**[36] and **Table 19**.

Table 18 Water data reporting template - Sample 1

Particular	Unit	Value
Water withdrawal from source		
Surface water (total)	ML	
- Freshwater	ML	
- Other water	ML	
Groundwater (total)	ML	
- Freshwater	ML	
- Other water	ML	
Seawater	ML	
Produced water	ML	
Third-party water	ML	
Total water withdrawal	ML	
Water Consumption		
Total consumption	ML	

[36] *GRI Standards, GRI 303- Water and Effluents, 2018*

Table 19 Water data reporting template - Sample 2

Particular	Unit	Facility A	Facility B	Facility Z
Water withdrawal from source				
Surface water	ML			
Groundwater	ML			
Seawater	ML			
Produced water	ML			
Third-party water	ML			
Total water withdrawal	ML			
Water Consumption				
Total consumption	ML			

4.2.2. Data analysis

Post the data collection step, it is essential to maintain a steady (daily, weekly, monthly) process to chart water consumption at different areas. Analyzing consumption patterns will provide quality information on abnormalities in water use. Analysis of data could result in the emergence of water use patterns which may indicate sudden high consumption levels or leaks within the system. Such level of detail may help the organisation to take prompt action, wherever necessary, to fix leaks thereby minimizing water wastage.

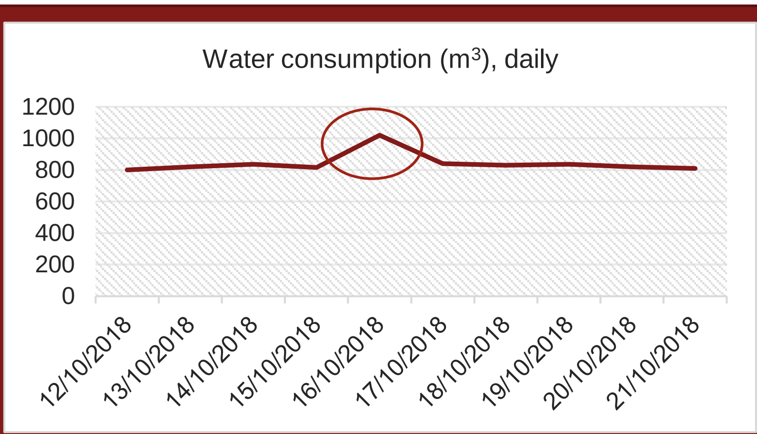


Illustration of a daily water consumption analysis chart with a sudden peak, probably indicating a probable leak

Organisations could also consider undertaking analysis of metered readings on a day-to-day basis to identify any anomalies in the water use patterns during the course of 24-hours.

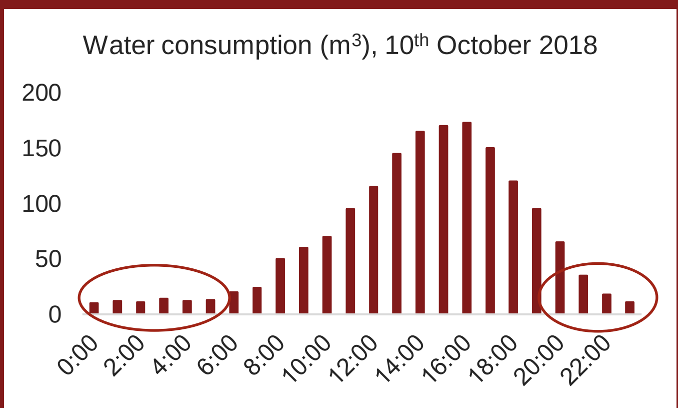
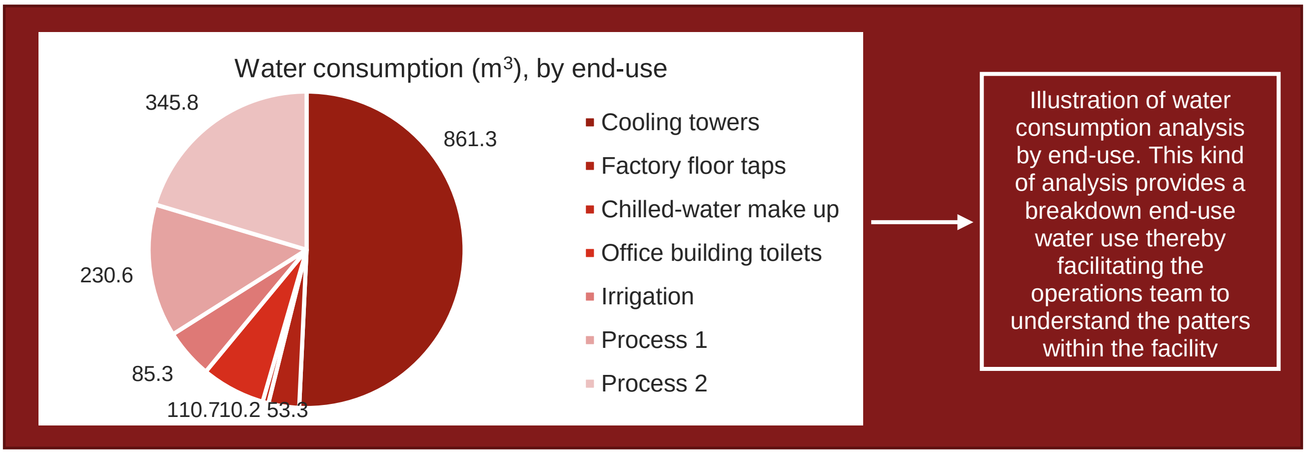
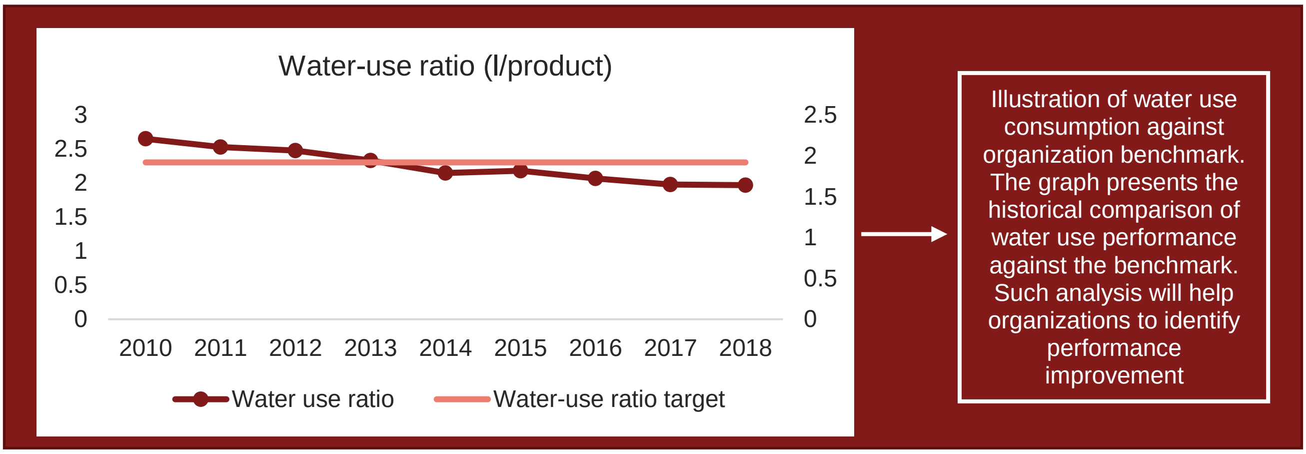


Illustration of a 24-hour water use consumption analysis. The graph shows that water use during the night is minimum as captured by the various meters installed across the facility. The graph also shows that water use has reduced during the off-peak hours due to the reduced number of activities.

Such analysis might assist organizations in identifying potential leakage and evaluating water loss in the system within the facility.





Water balance assessment

Water flow diagrams are essential for assessing the overall water balance of the industrial facility. This diagram enables organisations understand the flow of water from the various sources to the end-uses. The diagram (typical e.g. **Figure 16**) also facilitates in decision-making, by assessing and validating strategies and targets.

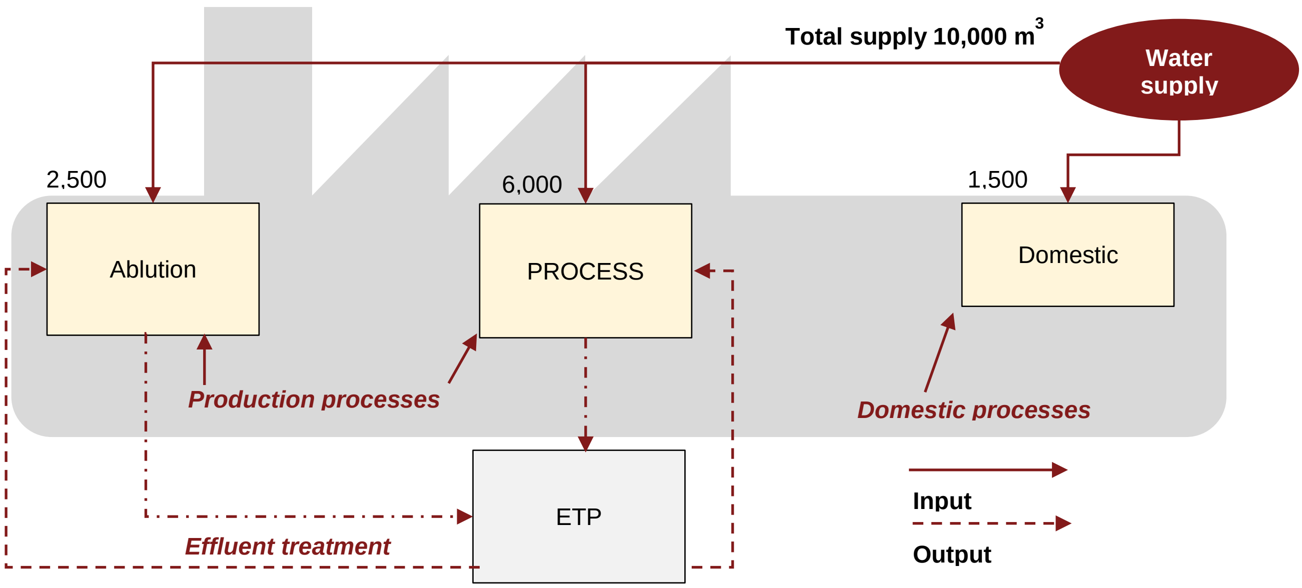


Figure 16 Sample water balance of industry

4.3. Specific energy and water consumption

As energy and water consumption are absolute quantities, it cannot be used as an index of comparison. The specific consumption is defined as energy or water consumption per unit of production i.e. tonnes of oil equivalent per tonne and cubic meter of water per tonne. The specific energy consumption (SEC) and specific water consumption (SWC) reveal interesting information for data analysis. Typically SEC and SWC variation within one standard deviation range is acceptable. The specific consumption helps in evaluation of the performance of an industrial unit by comparison with indicators. Sample energy & water consumption and production profile analysis is presented in **Table 20**.

Table 20 Sample specific energy and water consumption

Particular	Unit	Value
Production	tonne/year	15,750
Energy consumption	toe/year	1,075
Water consumption	m^3/year	18,845
Specific energy consumption	**kgoe/tonne**	**68.2**
Specific water consumption	**m^3/ tonne**	**1.2**

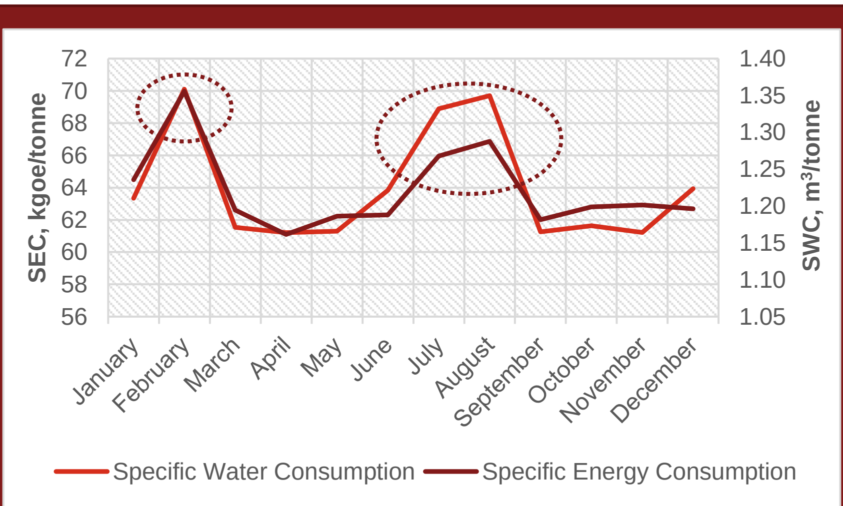


Illustration of specific energy and water consumption.

For month of February, July and August the specific consumption of water and energy was substantially higher than average consumption

5 Energy management and efficiency

5. Energy Management

Improving energy efficiency in industrial facilities needs to be done within the context of an energy management system (EnMS). Within any EnMS in an existing plant, the best way to maximise the quantity of energy savings and minimising investment cost is to follow a five-stage process based on the energy maturity matrix shown in **Figure 17**[37].

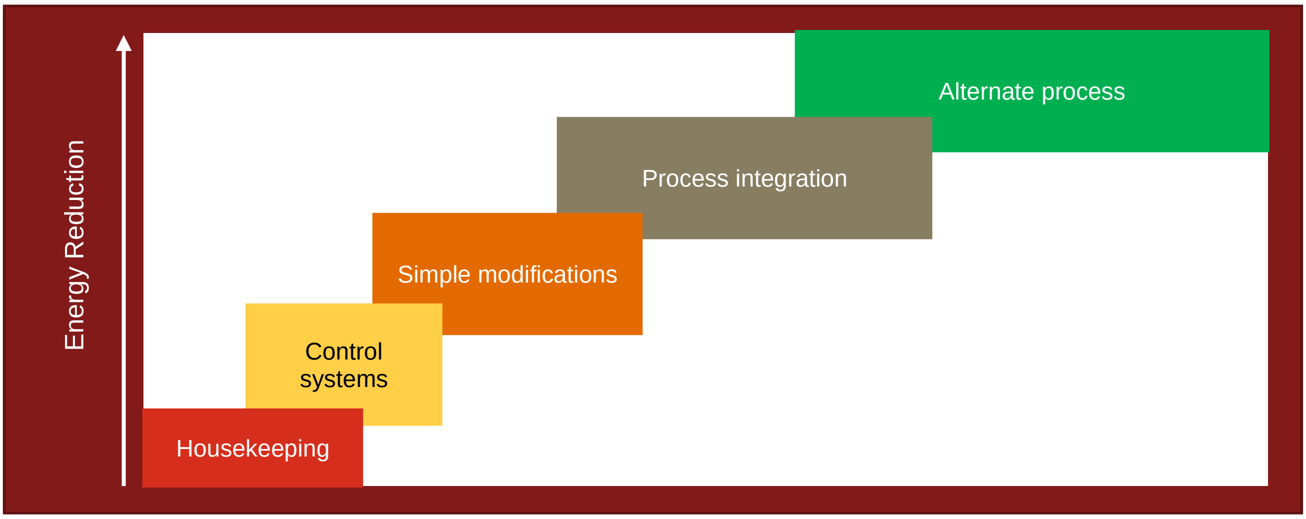


Figure 17 Energy maturity model

Good housekeeping

The first step is to prioritize housekeeping opportunities. Frequently, the opportunities that cost little or nothing include: implementing good maintenance, turning things off when they are not needed, reinstating and improving insulation and air leakage, reducing waste, leaks, idle time, production rate losses, and turning off taps & hoses when not needed. The benefit from steadfast and zero tolerance in good housekeeping is a reduction of energy consumption and this can reduce the size and capital investment of subsequent energy-saving opportunities.

Use of control systems

The introduction and tightening of the control systems of existing processes and utilities can further dampen variation in energy consumption and allow a process to operate closer to its designed control limits. Some small investment may be necessary to repair, reinstate, replace and/or introduce new control parameters.

Need for systems thinking

Integration of energy use is a more complex form of plant modification and retrofit but gives further energy savings. Some example includes: recovering heat from one process to be reused in another process, thermal pinch analysis, process intensification, de-bottlenecking and uprating, and overall plant or site-wide optimisation to minimise overall energy consumption.

Changes in process design and/or energy supply

The highest form of energy maturity, giving the biggest energy savings, comes from a step change either in process design, energy supply, or both. This is the most costly and carries the highest business risks compared to other projects in the energy maturity matrix.

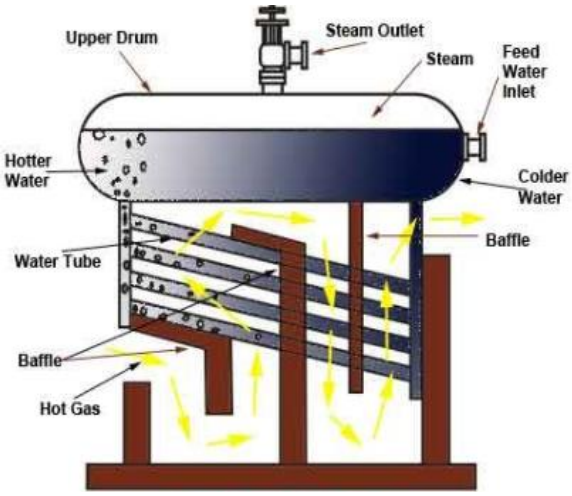
[37] *Fawkes, S., Oung et.al., Best Practices and Case Studies for Industrial Energy Efficiency Improvement, UNEP DTU Partnership*

5.1. Performance assessment of equipment

Performance assessment of most common equipment in Zimbabwe's industries are presented in this section.

5.1.1. Boiler[38]

A boiler is an enclosed vessel that provides a means for combustion heat to be transferred into water until it becomes heated water or steam. The key elements of a boiler are burner, combustion chamber, heat exchanger, exhaust stack, and controls. Typically boilers are classified as fire tube or water tube depending on type of media in the tubes. A pictorial view of water tube boiler is shown here. Though there are infinite numbers of boiler designs, these can be generally they fit into one of above two categories.



Source: https://www.electrical4u.com

The two performacne parameter of boiler are evaporation ratio and efficiency. The efficiency can be estimated either by direct method or indirect method.

5.1.1.1. Direct method

The direct method is also known as 'input-output method' due to the fact that it needs only the useful output (steam) and the heat input (i.e. fuel) for evaluating the efficiency. Efficiency can be evaluated using the formula

$$Boiler\ efficiency = \frac{Heat\ output}{Heat\ input} \times 100$$

Parameters to be monitored for the calculation of boiler efficiency by direct method are:

- Quantity of steam generated per hour (Q) in kg/hr.
- Quantity of fuel used per hour (q) in kg/hr.
- The working pressure (in kg/cm2 (g)) and superheat temperature (°C), if any
- The temperature of feed water (°C)
- Type of fuel and gross calorific value of the fuel (GCV) in kcal/kg of fuel

$$Boiler\ efficiency = \frac{Q \times (h_g - h_f)}{q \times GCV} \times 100$$

Where, h_g – Enthalpy of saturated steam in kcal/kg of steam, h_f - Enthalpy of feed water in kcal/kg of water

5.1.1.2. Indirect method

Indirect method is also called as heat loss method. The efficiency can be arrived at, by subtracting the heat loss fractions from 100. The principle losses that occur in a boiler are:

- Loss of heat due to dry flue gas
- Loss of heat due to moisture in fuel and combustion air
- Loss of heat due to combustion of hydrogen
- Loss of heat due to radiation
- Loss of heat due to unburnt

[38] *Boiler, BEE Guide Book, http://www.em-ea.org/Guide%20Books/book-4/4.1%20Boiler.pdf*

The performance evaluation through indirect method is presented in **Figure 18**. The indirect efficiency of the boiler is evaluated using formula.

$$Efficiency = 100 - \sum Losses$$

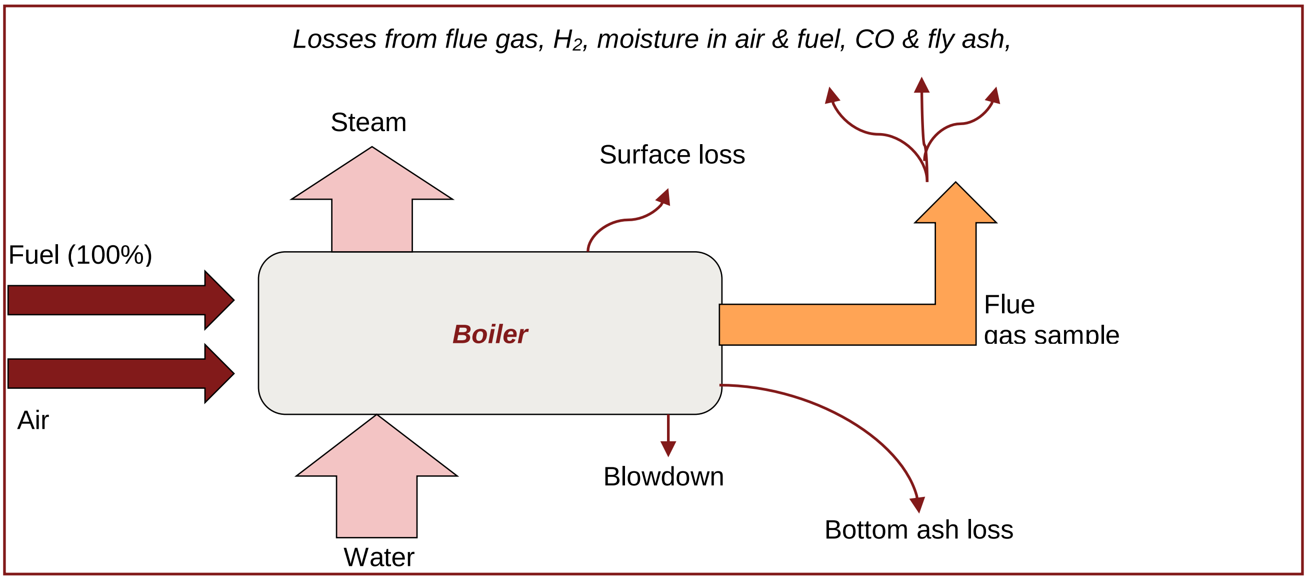
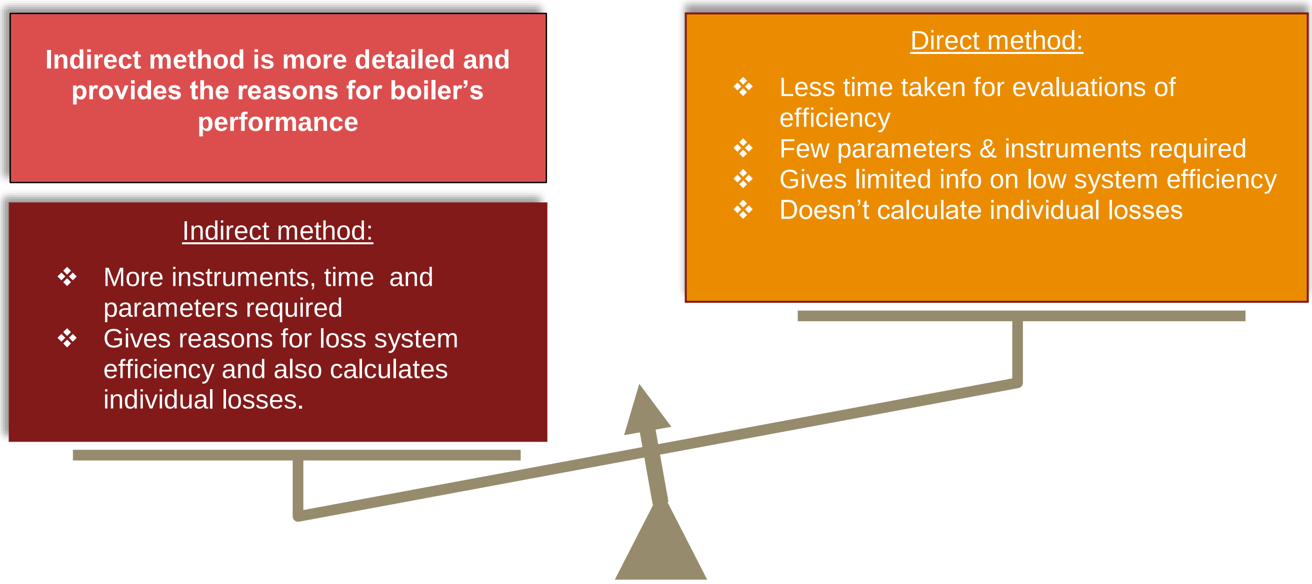


Figure 18 Indirect efficiency depiction

The comparison of direct and indirect method is presented below:



5.1.1.3. Evaporation ratio

Boiler Evaporation Ratio means kilogram of steam generated per kilogram of fuel consumed. However, this figure will depend upon type of boiler, calorific value of the fuel and associated efficiencies. It can be calcualted using the following formula.

$$Evaporation\ ratio = \frac{Heat\ utilized\ for\ steam\ generation}{Heat\ addition\ to\ steam} = \frac{kilogram\ of\ steam\ generated}{kilogram\ of\ fuel\ consumed}$$

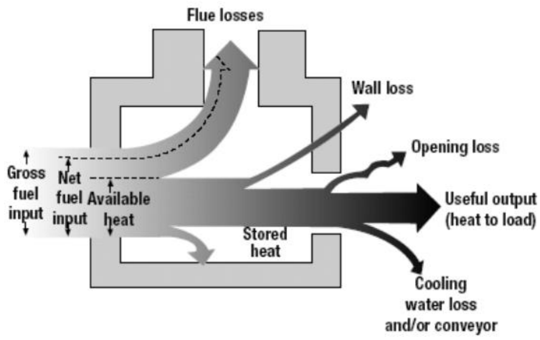
5.1.2. Furnace[39]

A furnace is an equipment to melt metals for casting or heat materials for change of shape (rolling, forging etc) or change of properties (heat treatment). A furnace has numerous applications such as:

Physical processing	Carbonization	Calcination	Roasting	Heating	Sintering	
Chemical processing	Electrolysis	Refining	Melting	Smelting	Reduction	Converting

The furnace can be classified based on fuel used, mode of charging, mode of heat transfer and mode of waste heat recovery. The performance indicator of a furnace are efficiency (%) and specific energy consumption. The efficiency is evaluated in similar way as that of a boiler i.e. either by direct or indirect method. The typical furnace losses includes:

- Heat storage in the furnace structure
- Losses from the furnace outside walls or structure
- Heat transported out of the furnace by the load conveyors, trays, fixtures, etc.
- Radiation losses from openings, hot exposed parts, etc.
- Heat carried by the cold air infiltration into the furnace
- Heat carried by the excess air used in the burners.



Source: BEE Guide Book

Thermal efficiencies of typical furnaces are shown in **Table 21**.

Table 21 Typical thermal efficiency of industrial furnace

Furnace type	Typical thermal efficiency (%)
Low temperature furnace	
540 - 980 °C (Batch type)	20 - 30
540 - 980 °C (Continuous type)	15 - 25
Coil Anneal (Bell) radiant type	5 - 7
Strip Anneal Muffle	7 - 12
High temperature furnace	
Pusher, Rotary	7 - 15
Batch forge	5 - 10
Continuous Kiln	
Hoffman	25 - 90
Tunnel	20 - 80
Ovens	
Indirect fired ovens (20–370 °C)	35 - 40
Direct fired ovens (20–370 °C)	35 - 40

The specific energy consumption of the furnace is given by the formula.

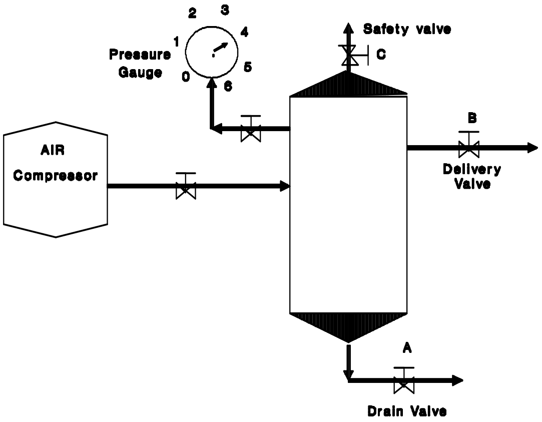
$$SEC_{furnace} = \frac{Quantity\ of\ fuel\ or\ energy\ consumed}{Quantity\ of\ material\ processed}$$

[39] *Furnace, BEE Guide Book, http://www.em-ea.org/Guide%20Books/book-2/2.4%20Furnaces.pdf*

5.1.3. Air compressor[40]

Air compressors are used in a variety of industries to supply process requirements, to operate pneumatic tools and equipment, and to meet instrumentation needs. Compressors are broadly classified as: Positive displacement compressor and Dynamic compressor. The performance indicators of an air compressor are specific power consumption, Free Air Delivery (FAD), and Leakage per cent.

5.1.3.1. Capacity assessment



The capacity of the air compressed is assessment by conducting a FAD test.

$$Q = \frac{(P_2 - P_1)}{P_0} \times \frac{V}{t}$$

Where: Q = Free air delivery (m^3/min)

P_2 = Final pressure after filling ($kg/cm^2{}_a$)

P_1 = Initial pressure after bleeding ($kg/cm^2{}_a$)

P_0 = Atmospheric pressure ($kg/cm^2{}_a$)

V = Storage volume (m^3)

t = Time take to build up pressure to P_2 (minutes)

In case of high suction air temperature as compared to ambient air temperature, use correction factor:

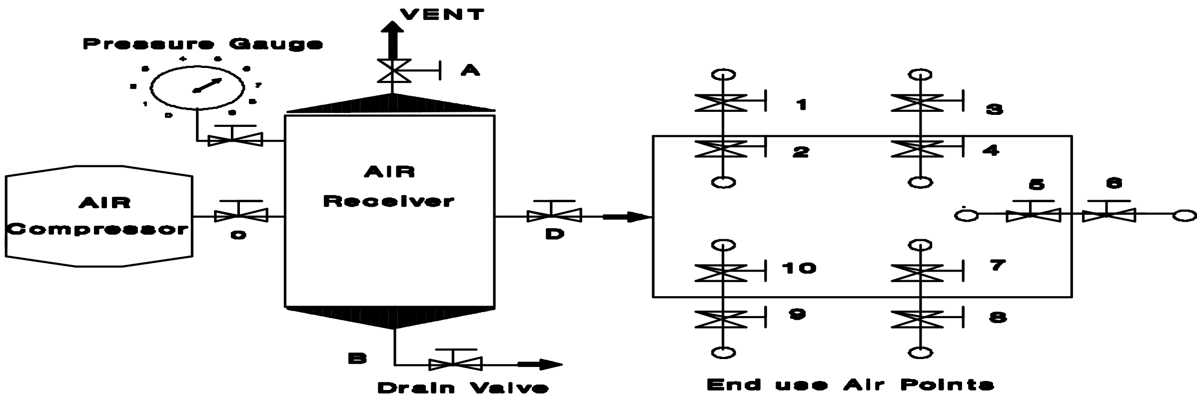
$$Q_{corrected} = \frac{(273 + T_{ambient})}{(273 + T_{suction})}$$

5.1.3.2. Leakage assessment

Leak detector can be used to identify the specific compressed air leakages locations. The leakages test can be used to identify total per cent or quantity of leakage in the system. Leakage can be calculated using formula:

$$Q_L = \frac{Q \times t_{on}}{(t_{on} + t_{off})}$$

Where: Q_L = Leakage quantity , t_{on} = On load time i.e. loading period (seconds), t_{off} = Off load time i.e. unloading period (seconds)



5.1.3.3. Specific power consumption

The specific power consumption of air compressor can be calculated by following formula

$$SPC = \frac{Power\ input\ (kW)}{FAD\ of\ compressor\ (cfm)}$$

[40] Air compressor, BEE Guide Book, http://www.em-ea.org/Guide%20Books/book-3/Chapter%203.3%20Compressed%20Air%20System.pdf

5.1.4. Electric motor

Motors convert electrical energy into mechanical energy by interaction between the magnetic fields set up in the stator and rotor windings. Motor driven systems account for ~ 55% of global industrial electricity consumption. The performance indicator of a motor are its efficiency and loading. The input power of the motor can be calculated using the formula:

$$P_{in} = \frac{\sqrt{3} \times V \times I \times pf}{1000}$$

Where: P_{in} - Three Phase power in kW, V- RMS Voltage, mean line to line of 3 Phases, I- RMS Current, mean of 3 phases, PF- Power factor as Decimal

The loading of the motor can be estimated using the following formula

$$Loading\ \% = \frac{P_{in}}{\left({P_r}/{\eta}\right)} \times 100$$

Where: P_r - rated power of motor and η - efficiency of motor

5.1.5. Pumps

Pumps come in a variety of sizes for a wide range of applications. They can be classified according to their basic operating principle as dynamic or displacement pumps. A centrifugal pump is of a very simple design and most commonly used pump design. The performance of pumps can be assessed using following formula

$$\eta = \frac{P_h}{P_s} = \frac{\left({[Q \times (h_d - h_s) \times \rho \times g]}/{1000}\right)}{P_s}$$

Where: Q - fluid flow rate (m^3/s); h_d - discharge head (m); h_s - suction head (m); ρ - density of fluid (kg/m^3) g - acceleration due to gravity; P_H - Hydraulic power; P_S - Shaft power; η - Efficiency

5.1.6. Fans

Fans and blowers provide air for ventilation and industrial process requirements. Fans generate a pressure to move air (or gases) against a resistance caused by ducts, dampers, or other components in a fan system. Fan and blower selection depends on the volume flow rate, pressure, type of material handled, space limitations, and efficiency. Fan efficiencies differ from design to design and also by types.

$$\eta_m = \frac{Q \times \Delta p}{102 \times P_s} \times 100 \qquad \eta_s = \frac{Q \times \Delta p_s}{102 \times P_s} \times 100$$

Where: Δp - Total pressure (mmWC); Δp_s - Static pressure (mmWC); P_s - Shaft power (kW); Q - fluid flow rate (m^3/s); η_m = Mechanical Efficiency; η_s = Static Efficiency

5.1.7. HVAC

Heating, Ventilation and Air Conditioning (HVAC) and refrigeration system transfers the heat energy from or to the products, or building environment. Energy in form of electricity or heat is used to power mechanical equipment designed to transfer heat from a low-energy level to a high-energy level.

The tonnes of refrigeration (TR) provided by system can be estimated by following relation:

$$TR = \frac{Q \times c_p \times (T_i - T_o)}{3024}$$

Where: TR - cooling TR duty, Q - mass flow rate of coolant (kg/hour), Cp - coolant specific heat (kCal /kg °C), T_i - inlet Temperature of coolant to evaporator (chiller) (°C), T_o - outlet temperature of coolant from evaporator (chiller) (°C)

The performance indicator are Coefficient of performance (COP) and specific power consumption (SPC). The COP is the ratio of cooling effect to the power input to compressor. Cooling effect is the difference in enthalpy across the evaporator.

$$COP = \frac{Cooling\ effect\ (kW)}{P_{compressor}\ (kW)} \qquad SPC = \frac{P_{compressor}(kW)}{TR_{cooling}(TR)}$$

5.2. Energy Efficiency Technologies

5.2.1. Energy Efficient Melting Furnace[41]

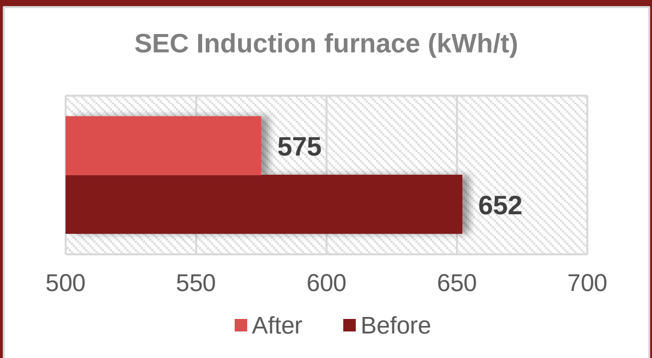
Box 2: Energy Efficient Induction Melting Furnace

Baseline scenario: A foundry unit producing 2,540 tonnes of casting per annum was equipped with a 750 kg capacity induction furnace for melting. The furnace was SCR (Silicon Controlled Rectifier) type and was outdated technology. The power logging of induction furnace revealed the specific energy consumption was 652 kWh per tonne liquid metal on average, with some batches having SECs above 700 kWh per tonne liquid metal.

Proposed solution: A new energy efficient technology IGBT (Insulated Gate Bipolar Transistor) based induction furnace was recommended. The IGBT type has a conversion efficiency of 97% when compared to max. 95% of SCR type. A high power factor of 0.99 is achieved throughout the melt cycle. These units are smaller and more compact than prior silicon controlled rectifier units in this size range. The new furnace included includes an intelligent digital control board with fiber-optic connectors for clear signal processing, a digital display and an integral keypad for control and data entry. The proposed furnace was of 650 kW power rating and 750 kg crucible.

Savings:

- Specific energy saving – 77 kWh/t
- Annual monetary savings – US $ 15,550
- Simple payback – 25 months
- Energy savings – 11.8 %
- GHG reduction potential: 380 t CO_2/year



[41] *WB-SIDBI-GEF Project, Financing Energy Efficiency at MSMEs*

5.2.2. Screw compressor for refrigeration system

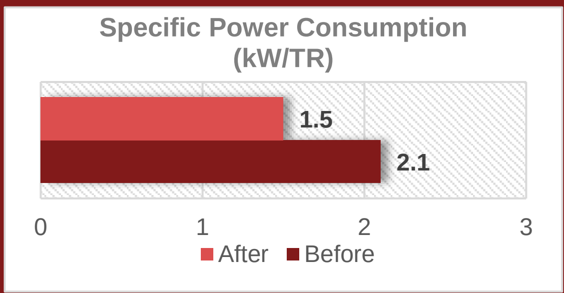
Box 3: Screw compressor for refrigeration system

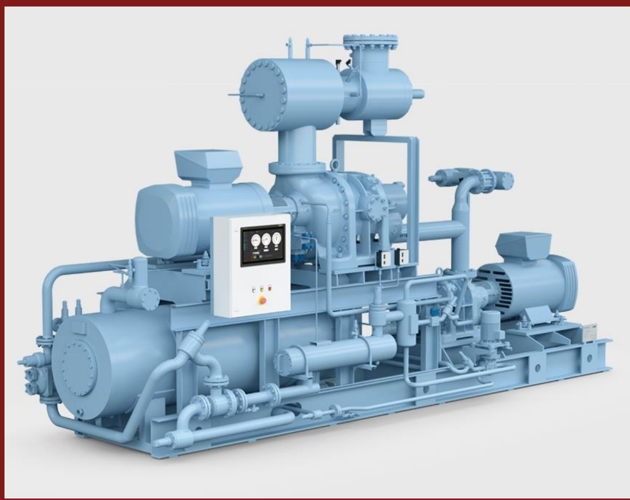
Baseline scenario: A fish processing plant had 150 TR ammonia based refrigeration system installed to meet is refrigeration needs. The system was equipped with four numbers of reciprocating compressors which are characterized by higher specific power consumption.

Proposed solution: It was recommended to replace the reciprocating compressors with screw type compressors. Screw compressors rotate in one direction thereby causing less noise, heat and vibration. As wear & tear is very low, the maintenance cost is lower than reciprocating.

Savings:

- Annual electricity saving – 540 MWh
- Annual monetary savings – US $ 62,310
- Simple payback – 20 months
- Energy savings – 28.6%
- GHG reduction potential: 480 t CO_2/year





5.2.3. Energy efficient motor (IE3)

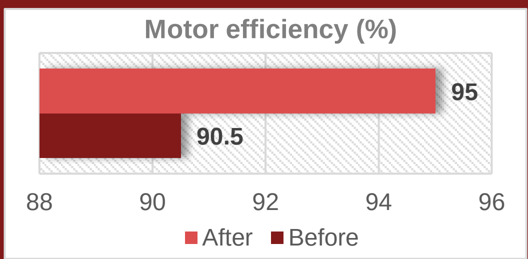
Box 4: Energy efficient motor (IE3)

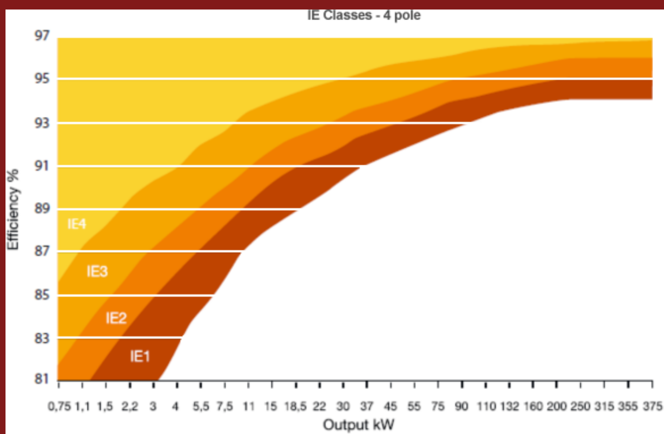
Baseline scenario: A blower in a crusher industry was driven by a 75 kW electric induction motor. The motor was a standard motor with no rating. Moreover motor was rewound twice. Operational hours: 6000.

Proposed solution: An IE3 rated motor was recommended to replace the standard motor. IE is "International Efficiency" with class 1, 2 & 3 i.e. IE1 & IE2 & IE3. The energy savings of IE3 motors are mainly based on lower nominal currents. IE3 motors are extremely sturdy and well designed.

Savings:

- Annual electricity saving – 13,830 kWh
- Annual monetary savings – US $ 1,820
- Simple payback – 4 years
- GHG reduction potential: 12 t CO_2/year





5.2.4. Biomass briquette fired boiler

Box 5: Biomass briquette fired boiler

Baseline scenario: A pharmaceutical industry has a 4.5 tonne per hour capacity diesel fired boiler installed to meet its process steam requirements. Boiler operated at 10.5 kg/cm^2 pressure. The diesel cost is increasing steadily cutting into profit margin of the industry.

Proposed solution: An alternative fuel source at a lower cost was proposed to the industry. Locally available biomass was briquetted using a briquetting machine and used as alternate fuel.

Savings:

- Annual diesel saving – 159.3 kL
- Annual monetary savings – US $ 134,790
- Simple payback – 9 months
- GHG reduction potential: 410 t CO_2/year

5.2.5. Vertical rolling mill

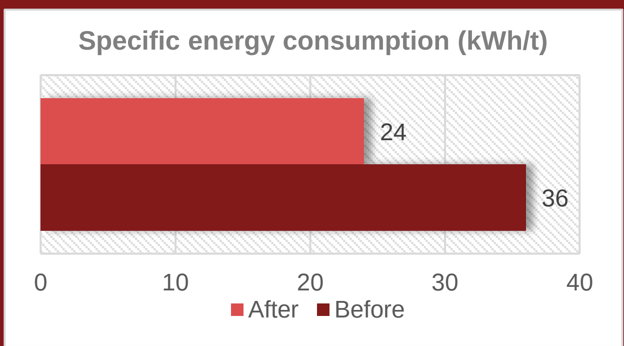
Box 6: Vertical rolling mill

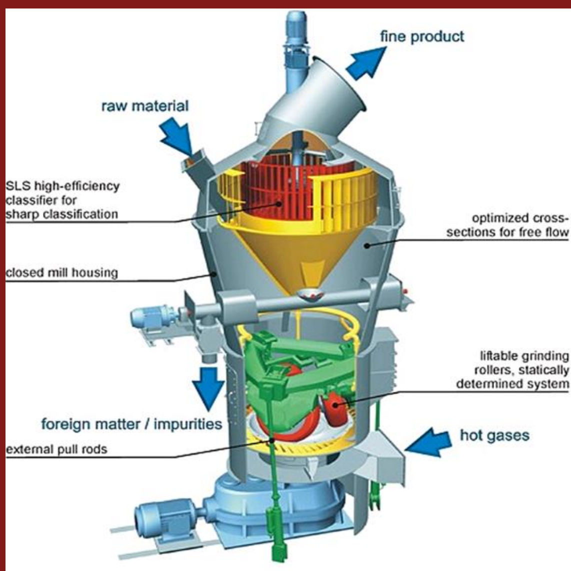
Baseline scenario: A cement industry has a cement mill equipped with ball mill with separator and cyclone for grinding of capacity 270 tonne per hour.

Proposed solution: Vertical Roller Mills (VRM) are characterized with lower specific power consumption, maintenance cost, better reliability & product quality. It was recommended to replace ball mill with VRM.

Savings:

- Annual electricity saving – 5,740 MWh
- Annual monetary savings – US $ 620,150
- Simple payback – 18 months
- Energy savings - 30%
- GHG reduction potential: 2,220 t CO_2/year





5.2.6. Regenerative burners for reheating furnace[42]

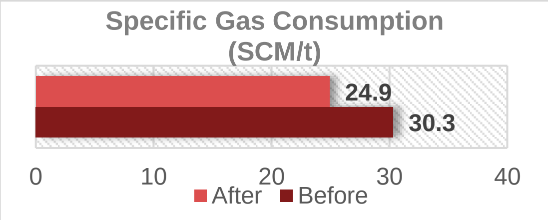
Box 7: Regenerative burners for reheating furnace

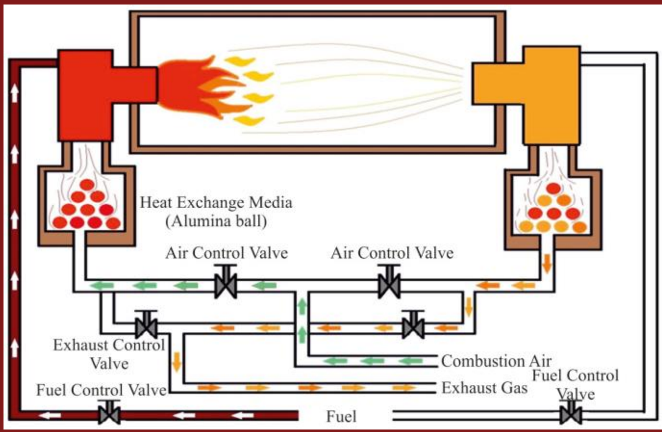
Baseline scenario: A steel rolling industry with an annual production of 89,300 tonnes is equipped with a 45 tonne per hour capacity reheating furnace. The furnace study revealed the specific energy consumption of 30.3 SCM natural gas per tonne. The flue gas temperature was observed 375 °C.

Proposed solution: Regenerative combustion technology, it allows regenerator in burners to accomplish heat exchange between flue gas and combustion air and achieve the effects of high thermal efficiency, reduction in operating cost and low emissions.

Savings:

- Annual fuel saving – 1,259,000 SCM
- Annual monetary savings – US $ 373,080
- Simple payback – 4 years
- GHG reduction potential: 2,205 t CO_2/year





5.2.7. Gas heat pump[43]

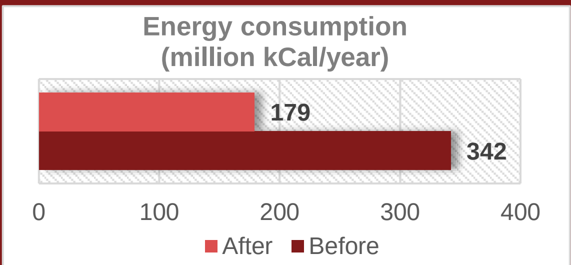
Box 8: Gas heat pump

Baseline scenario: A investment casting unit producing precision steel casting has a conventional air conditioning system for drying the wax moulds. Electrical energy is used for the purpose. Conventional system uses R-22 refrigerant, an ozone depleting substance.

Proposed solution: Installation of an energy efficient GHP air conditioning system was recommended. GHP uses a NG-based engine to drive compressor, and refrigerant used is R410A (ozone friendly). The GHP system was designed and customized by a Japanese manufacturer, YANMAR Energy System Co. Ltd

Savings:

- Annual monetary savings – US $ 14,350
- Simple payback – 2.8 years
- Energy saving - 48 %
- GHG reduction potential: 54 t CO_2/year



[42] *TERI 2014, Energy Efficient Technologies and Best Practices in Steel Rolling Industries (Indonesia)*
[43] *Case study, http://sameeeksha.org/pdf/investment-casting-unit-in-Rajkot-adopts-LCT.pdf*

5.3. Energy Efficiency Retrofits

5.3.1. Air Pre-heater for HAG

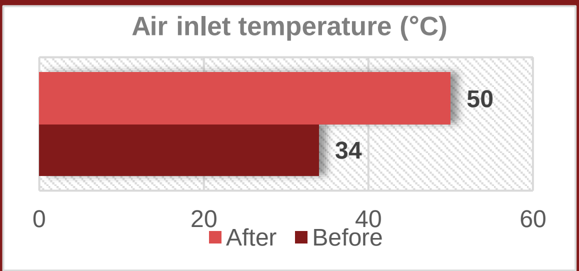
Box 9: APH for HAG

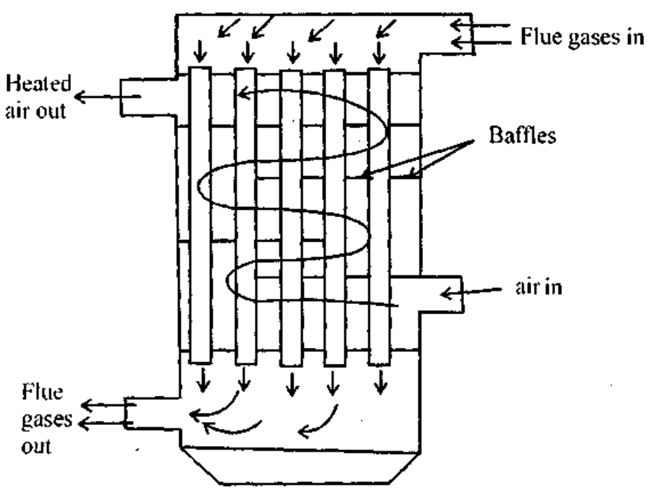
Baseline scenario: An agrochemical industry has installed a natural gas fired hot air generator (HAG) on a Spin Flash Dryer. The flue gases of the HAG were above 500°C and were released to environment.

Proposed solution: Installation of air pre-heater was recommended. A cross flow type shell and tube heat exchanger with heat transfer area 4.7 m^2 was installed.

Savings:

- Annual natural gas saving - 8,077 SCM
- Annual monetary savings – US $ 5,350
- Simple payback – 6 months
- Energy saving - 4.9 %
- GHG reduction potential: 15 t CO_2/year





5.3.2. Economizer for boiler

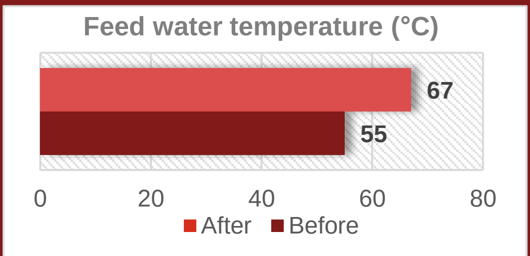
Box 10: Economizer for boiler

Baseline scenario: A pharmaceutical industry has installed a 1000 kg per hour natural gas fired boiler for meeting its steam requirement in the process. The hot flue gases from the boiler were released out.

Proposed solution: Installation of economizer on the boiler was recommended to pre-heat the feed water. A cross flow type shell and tube heat exchanger with heat transfer area 3.3 m^2 was installed. The average water feed rate of the system was 565 kg per hour.

Savings:

- Annual natural gas saving - 6,478 SCM
- Annual monetary savings – US $ 4,310
- Simple payback – 7 months
- Energy saving - 2.5 %
- GHG reduction potential: 12 t CO_2/year



5.3.3. De-Super Heater on Chiller Condenser

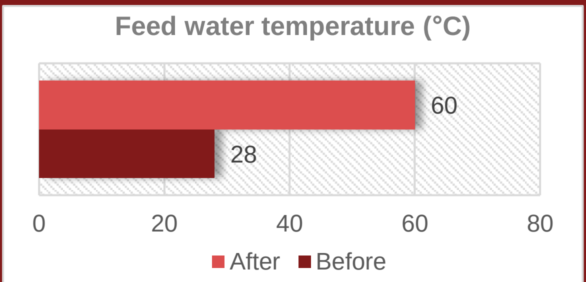
Box 11: De-Super Heater on Chiller Condenser

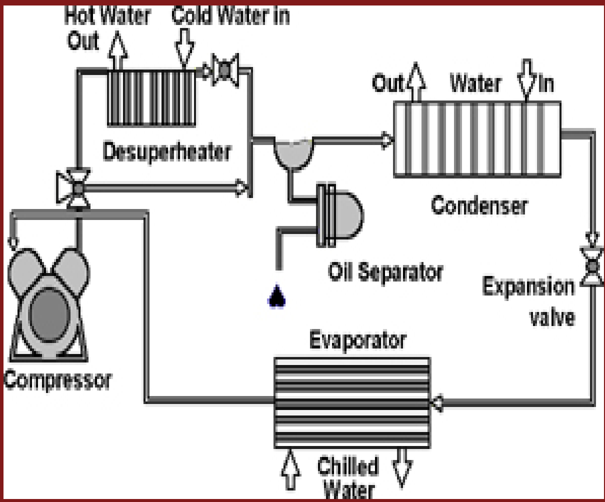
Baseline scenario: A food industry has 4 screw type chillers of 408 TR capacity. The plant also has a boiler with total water feed rate of 4.9 tonne per hour.

Proposed solution: The ammonia from the compressor is at very high temperature, the heat is rejected in condenser. It is recommended to install a de-super heater between compressor and condenser. De-super heater is a counter flow plate type heat exchanger. It heats the boiler feed water.

Savings:

- Annual natural gas saving - 123,790 SCM
- Annual monetary savings – US $ 84,310
- Simple payback – 20 months
- Energy saving - 4.1 %
- GHG reduction potential: 220 t CO_2/year





5.3.4. Soft starter on motor for hydraulic machine

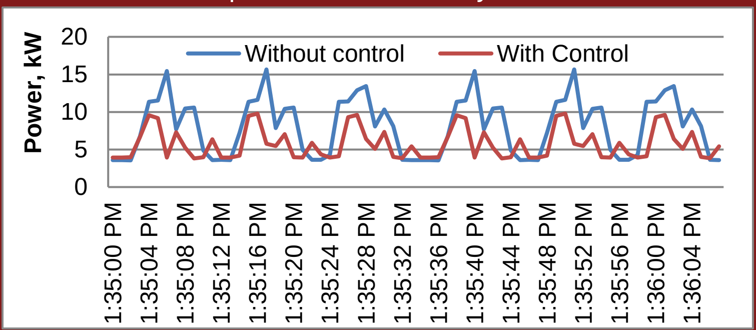
Box 12: Soft starter on motor for hydraulic machine

Baseline scenario: A sheet metal fabrication industry is equipped with 20 numbers of 180 ton hydraulic press. The hydraulic press are run by induction motor and they are connected direct on line.

Proposed solution: The starting current of the hydraulic press connected DOL is high. Moreover the power factor of the motor is low. It was recommended to install soft starter coupled with capacitor bank on each of the hydraulic press.

Savings:

- Annual electricity saving - 25,750 kWh
- Annual monetary savings – US $ 3,350
- Simple payback – 1 month
- GHG reduction potential: 23.5 t CO_2/year



5.3.5. Star- delta convertor for motors

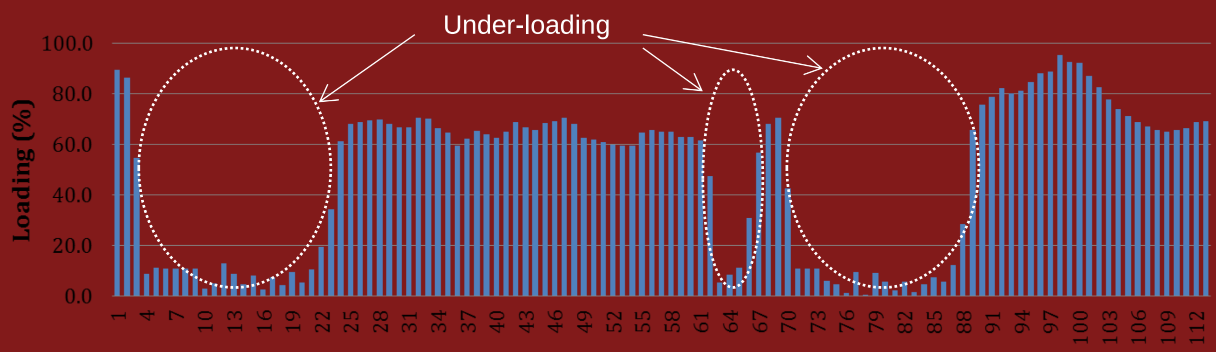
Box 13: Star- delta convertor for motors

Baseline scenario: A food processing industry has 112 induction motors installed. Quite a few motors in the plant were under loaded.

Proposed solution: All motors with loading under 40% were recommended to be retrofitted with star-delta convertor.

Savings:

- Annual electricity saving - 68,150 kWh
- Annual monetary savings – US $ 7,865
- Simple payback – 9 month
- GHG reduction potential: 60 t CO_2/year

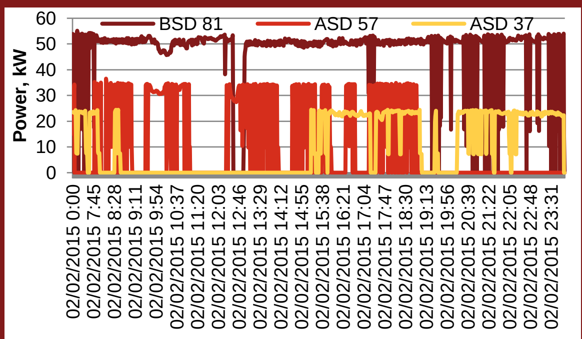


5.3.6. Sequence controller for air compressors

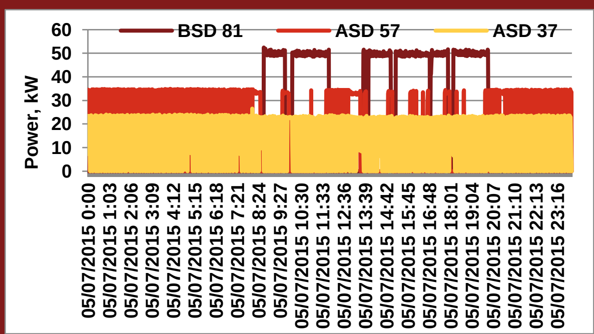
Box 14: Sequence controller for air compressors

Baseline scenario: An auto ancillary unit has three screw type air compressors installed with combined capacity of 600 cfm. All three compressor operate ad hoc.

Proposed solution: It was recommended to install sequence controller with pressure transducer to control the three compressor operation based on demand.



Before: 1029 kWh/day



After: 775 kWh/day

5.3.7. Thermostatic controller for cooling tower

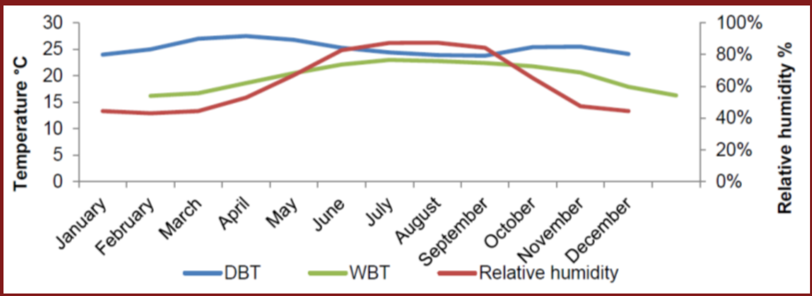
Box 15: Thermostatic controller for cooling tower

Baseline scenario: A steel industry producing 89,280 tonnes of steel per annum has a 2.5 million kCal capacity cooling tower. The cooling tower doesn't have any control systems, they are operated manually.

Proposed solution: It was recommended to install thermostatic controller, which will switch the fans On and OFF based on the temperature. The fans can go OFF whenever the WBT and DBT are almost close.

Savings:

- Annual electricity saving - 14,115 kWh
- Annual monetary savings – US $ 960
- Simple payback – 10 month
- GHG reduction potential: 13 t CO_2/year
- CT fan power - 22 kW
- Power consumption - 14.7 kW
- WBT almost = DBT - 4 months



5.3.8. Modification in compressed air piping network

Box 16: Modification in compressed air piping network

Baseline scenario: A pump manufacturing industry meets its pneumatic and service air needs through three screw type air compressors. The network of air distribution is has changed as the industry has grown. Leading to unnecessary bends and over-complications.

Proposed solution: It was recommended to re-work on compressed air distribution network with minimum possible bends.

Savings:

- Annual electricity saving - 16,760 kWh
- Annual monetary savings – US $ 2,065
- Simple payback – 2 month
- GHG reduction potential: 15 t CO2/year

5.3.9. Variable Frequency Drive for air compressor

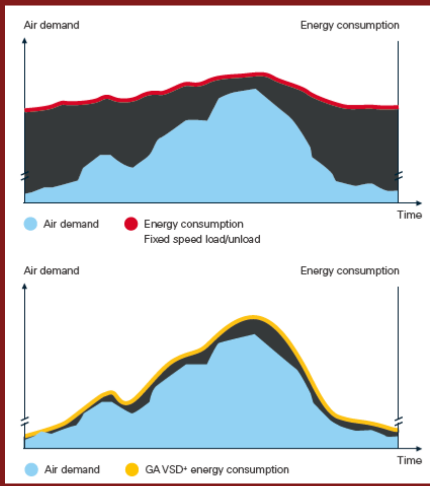
Box 17: Variable Frequency Drive for air compressor

Baseline scenario: A chemical industry meets in pneumatic air requirement by a 310 cfm capacity screw air compressor. The compressor is a fixed speed type. The loading on the compressor was observed 54%.

Proposed solution: It is recommended to retrofit the compressor with variable frequency drive (VFD) to reduce the speed and save energy during low demand period.

Savings:

- Annual electricity saving - 52,670 kWh
- Annual monetary savings – US $ 6,080
- Simple payback – 9 months
- GHG reduction potential: 43 t CO_2/year



5.3.10. Furnace crucible refractory lining optimization[44]

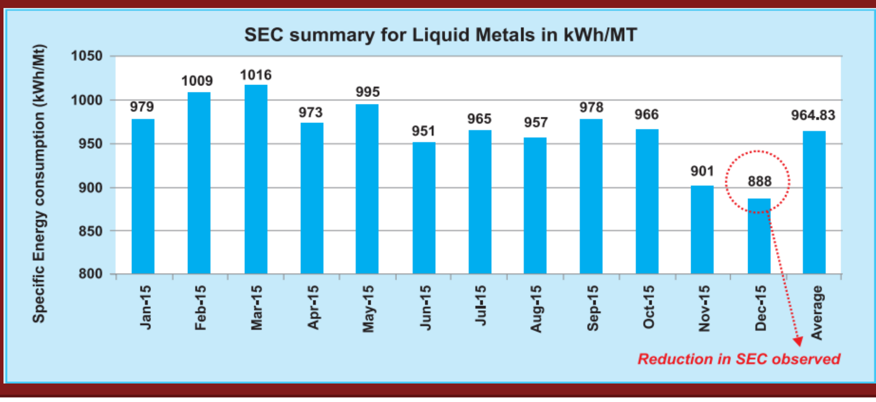
Box 18: Furnace crucible refractory lining optimization

Baseline scenario: A foundry unit using 500 kW induction furnace for melting stainless steel for producing castings for agriculture implements. The slag build-up on the furnace lining was substantial leading to increased energy consumption and lower batches capacity.

Proposed solution: It was recommended to re-line the furnace with superior refractory material. The benefits of implementation include: reduced SPC (8.3%), enhanced melt capacity (8%) and increased lining life (from 350 to 500 batches per lining).

Savings:

- Annual electricity saving - 210 MWh
- Annual monetary savings – US $ 22,500
- Simple payback – 2 months
- GHG reduction potential: 175 t CO_2/year



[44] *Furnace Crucible Refractory lining optimization, GEF-UNIDO-BEE Project*

5.3.11. Automatic double stage burner for boiler[45]

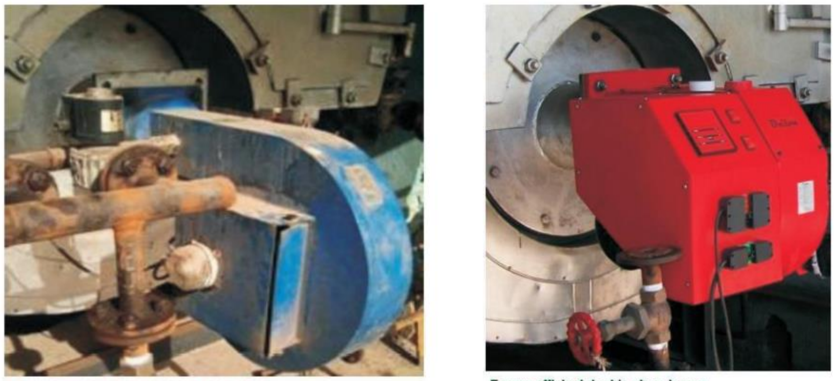
Box 19: Automatic double stage burner for boiler

Baseline scenario: A chemical industry producing different categories of textile chemicals, dyes and intermediates like violet acid, Koch's acid, Mixed Cleve's acid, Chicago acid and benzoyl H acid. The plant has a 1 tonne per hour, the burner of the boiler was low efficiency single stage and it was manually operated.

Proposed solution: It was recommended to replace existing low efficiency boiler with automatic double stage burner. The new energy efficient burner allows operation at both full and part loads, reducing the need to turn the burner on and off and thereby offering better performance.

Savings:

- Annual natural gas saving - 3,793 SCM
- Annual monetary savings – US $ 2,000
- Simple payback – 14 months
- GHG reduction potential: 7 t CO_2/year



Low efficiency single stage burner

Energy efficient double-stage burner

5.3.12. Solar water heater – Hot water for process

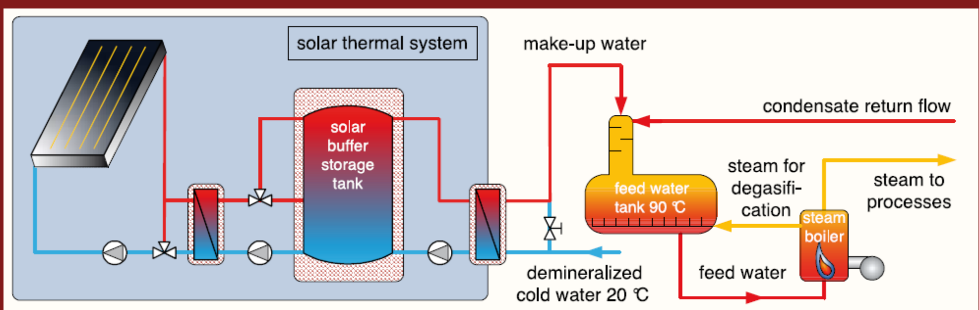
Box 20: Solar water heater – Hot water for process

Baseline scenario: A meat processing industry utilizes enormous amount of hot water for washing and cleaning. Hot water is generated using furnace oil as fuel.

Proposed solution: It was recommended to install solar water heater to supply hot water for the process. Solar thermal system - 290 m^2, Buffer storage capacity - 23 m^3, Hot water temperature - 65°C

Savings:

- Annual furnace oil saving - 25.7 tonne
- Annual monetary savings – US $ 41,580
- Simple payback - 4 years
- GHG reduction potential: 65 t CO_2/year



45 *Chemical unit adopts energy conservation measures, GEF-WB-SIDBI Project*

5.4. Best Operating Practices

5.4.1. Best operating and maintenance practices for boilers

A boiler is often the largest consumer of fuel in a factory or building. Any improvements that maintenance can make in its operation are therefore immediately reflected in decreased energy consumption and decreased energy cost. The important operating practice to be followed for boiler are as follows:

- Feed water tank and fuel oil tank should be covered from top
- Implement an effective water treatment program and blow down control
- Conduct regular checks to ensure the boiler efficiency is at optimal level
- Regular analysis of flue gases to identify excess air
- Maintain burners at proper adjustments
- Replace or repair any missing or damaged insulation
- Periodically calibrate measurement equipment and tune the combustion control system
- Maximum efficiency is achieved at about two third of the full load, therefore the load swings should be minimized and demand should be scheduled properly
- 3 mm of soot, (deposits on the boiler) can cause an increase in fuel consumption by 2.5 percent due to increased flue gas temperature
- For every 1 % reduction in excess air, there is approximately 0.6 % rise in efficiency
- In order to improve thermal efficiency by 1 %, the combustion air temperature must be raised by 20 ^{o}C
- A 10 percent blow down in 15 kg/cm^2 boiler results in 3 percent efficiency loss
- Three to five days before a scheduled shut down, increase the blow down by 50 percent and during the last 24 hours before shut down, decrease the continuous blow down and increase the manual blow down
- Monitor, evaluate and compare performance data regularly to derive accurate performance standards.

Typical problems in boiler and steam distribution system and their solutions is presented in **Table 22**[46].

Table 22 Boiler and steam distribution system: Problems and solutions

System Component	Problem	Initial Maintenance Action
Boiler	Inoperable gauges	Overhaul boiler controls as soon as possible
	Most recent boiler adjustment at least two years ago	Have boiler adjusted for most efficient firing
	Scale deposits on water side of shutdown boiler	Remove scale; check water-softening system
	Boiler stack temperature more than 150°F above steam or water temperature	Clean tubes and adjust fuel burner (Ref. 1)
	Fuel valves leak	Repair
	Stack shows black smoke or haze when boiler is operating	Check combustion controls
	Rust in water gauge	Check return line for evidence of corrosion (Ref. 2)
	Safety valves not checked or tagged	Have inspection performed immediately
Steam trap	Leaks	Have inspection performed; repair or replace
Steam valve	Leaks	Repair
Steam line	Lines uninsulated	Have insulation installed

[46] *Wayne C Turner, Steve Doty, Energy Management Handbook, Sixth Edition*

System Component	Problem	Initial Maintenance Action
	Water hammer noted	Fix steam trap
Condensate return	Uninsulated	Insulate if hot to touch
Condensate tank	Steam plumes at tank vents	Check and repair leaking steam traps
	No insulation	Install insulation
Condensate pumps	Excessive noise	Check and repair
	Leaks	Replace packing: overhaul or replace pump if necessary

Steam traps located on the equipment allow condensate to drain back into the condensate return line, where it flows back to the condensate receiver. Steam traps also perform other functions, such as venting air from the system on start-up. Comparison of steam traps types and its characteristics are presented in **Table 23**[46].

Table 23 Comparison of Steam Trap Characteristics

Characteristic	Inverted Bucket	F&T	Disk	Bellows Thermostatic
Method of operation	Intermittent	Continuous	Intermittent	Continuous [a]
Energy conservation (time in service)	Excellent	Good	Poor	Fair
Resistance to wear	Excellent	Good	Poor	Fair
Corrosion resistance	Excellent	Good	Excellent	Good
Resistance to Hydraulic shock	Excellent	Poor	Excellent	Poor
Vents air and CO_2 at steam temperature	Yes	No	No	No
Ability to vent air at very low pressure (1/4 psig)	Poor	Excellent	NR [b]	Good
Ability to handle start-up air loads	Fair	Excellent	Poor	Excellent
Operation against back pressure	Excellent	Excellent	Poor	Excellent
Resistance to damage from freezing [c]	Good	Poor	Good	Good
Ability to purge system	Excellent	Fair	Excellent	Good
Performance on very light loads	Excellent	Excellent	Poor	Excellent
Responsiveness to slugs of condensate	Immediate	Immediate	Delayed	Delayed
Ability to handle dirt	Excellent	Poor	Poor	Fair
Comparative physical size	Large [d]	Large	Small	Small
Ability to handle "flash steam"	Fair	Poor	Poor	Poor
Mechanical failure (open-closed)	Open	Closed	Open [e]	Closed [f]

[a] *can be intermittent on low load*
[b] *not recommended for low pressure operation*
[c] *cast iron traps not recommended*
[d] *in welded stainless steel construction - medium*
[e] *can fail closed due to dirt*
[f] *can fail open due to wear*

The amount of blowdown required for satisfactory boiler operation is normally based on allowable limits for water impurities as established by standards such as the American Boiler Manufacturers Association (ABMA). The recommended limits for ***boiler-water concentrations*** is presented in **Table 24**[46].

Table 24 Recommended Limits for Boiler-Water Concentrations

Drum pressure (psig)	Total Solids		Alkalinity		Suspended Solids		Silica
	ABMA	Possible	ABMA	Possible	ABMA	Possible	ABMA
0 to 300	3500	6000	700	1000	300	250	125
301 to 450	3000	5000	600	900	250	200	90
451 to 600	2500	4000	500	500	150	100	50
601 to 750	2000	2500	400	400	100	50	35
751 to 900	1500	—	300	300	60	—	20
901 to 1000	1250	—	250	250	40	—	8
1001 to 1500	1000	—	200	200	20	—	2

Optimum ***burner performance*** of the boiler is of prime importance. **Table 25**[46] lists common burner difficulties that can be rectified through observation and maintenance.

Table 25 Malfunctions in boiler firing system

Malfunction	Fuel			Detection	Action
	Coal	Oil	Gas		
Uneven air distribution to burners	x	x	x	Observe flame patterns	Adjust registers (trial and error)
Uneven fuel distribution to burners	x	x	x	Observe fuel pressure gages, or take coal sample and analyze	Consult manufacturer
Improperly positioned guns or impellers	x	x		Observe flame patterns	Adjust guns (trial and error)
Plugged or worn burners	x	x		Visual inspection	Increase frequency of cleaning; install strainers (oil)
Damaged burner throats	x	x	x	Visual inspection	Repair

Table 26[46] gives a list of the most common boiler maintenance actions that need to be performed annually. **Table 27**[46] gives a checklist of other routine maintenance items. If your staff is trained in boiler operation and maintenance this table can be used to help define a pattern of boiler maintenance.

Table 26 Boiler checklist for routine maintenance

Action	Frequency
Check safety controls	Daily
Check stack-gas analysis	Daily or more often
Blow down water in gauges	Weekly
Blow down sludge from condensate tanks	Whenever needed; frequency depends upon amount of makeup water used
Have water chemistry checked	Quarterly
Perform combustion efficiency check; log results	Daily or weekly
Check and record pressures and readings from boiler gauges	Daily or weekly

Table 27 Boiler checklist for annual maintenance

Check	Examine for
Safety interlocks	Operability—must work
Boiler trip circuits	Operability
Burner	
Oil tip openings	Erosion or deposits
Oil temperatures	Must meet manufacturer's specifications
Atomizing steam pressure	Must meet manufacturer's specifications
Burner diffusers	Burned or broken, properly located in burner throat
Oil strainers	In place, clean
Throat refractory	In good condition
Gas injection system	
Orifices	Unobstructed
Filters and moisture traps	In place, clean, and operating
Burner parts	Missing or damaged
Coal burners	
Burner components	Working properly
Coal	Fires within operating specifications
Grates	Excessive wear
Stokers	Location and operation
Air dampers	Unobstructed, working
Cinder reinjection system	Working, unobstructed
Combustion Controls	
Fuel valves	Move readily, clean
Control linkages and dampers	Excessive "play"
Fuel supply inlet pressures on atomizing	Meet manufacturer's specifications steam or air systems
Controls	Smooth response to varying loads
Gauges	Functioning and calibrated
Furnace	
Fire-side tube surfaces	Soot and fouling
Soot blowers	Operating properly
Baffling	Damaged; gas leaks
Refractory and insulation	Cracks, missing insulation
Inspection ports	Clean
Water treatment	
Gauges	Working properly
Blowdown valves	Working properly
Water tanks	Sludge
Water acidity	Within specifications

5.4.2. Best operating and maintenance practices for HVAC system

The purposes of HVAC systems are to supply enough air of the right temperature to keep people comfortable and to exhaust harmful or unpleasant air contaminants. **Table 28**[46] gives a list of some of the more expensive troubles that may be encountered.

Table 28 HVAC system - Problems and solutions

System Component	Problem	Initial Maintenance Action
Filter	Excessively dirty	Replace or clean
Damper	Blocked open or linkage disconnected	Check damper controls
	Leaks badly	Clean and overhaul
Ductwork	Open joints	Repair
	Loose insulation in duct work	Replace and attach firmly
	Water leakage or rust spots	Repair
	Crushed	Replace
Grillwork	Air fl ow impossible due to dirt	Remove and clean
	Blocked by equipment	Remove equipment
Fan	Motor not hooked up to fan	Disconnect motor or install fan belts
	Excess noise	Check bearings, belt tension mountings, dirty blades
	Insufficient ventilation	Check fan and surrounding duct work and grill work
	Belt too tight or too loose	Adjust motor mount
	Pulleys misaligned	Correct alignment
Pump	Hot-water pump is cold (or vice versa)	Inspect valving; check direction of flow
Blower	Not moving air in acceptable	Check direction of rotation and change wiring if needed;
Chiller	Leaks	Repair
Cooling tower	Scaling on spray nozzles	Remove by chipping or chemical means
	Leaks	Repair
	Cold water too warm	Check pumps, fans, and fill; clean louvers
	Excessive water drift	Check drift elimination, metering orifices, and basins; check for over-pumping
Compressor thermostat	Temperature reading not accurate	Calibrate
	Leaks water or oil from mounting	Check pneumatic control lines

5.4.3. Best operating and maintenance practices for electrical system

The industrial electrical distribution systems are often crudely designed and maintained , it can cause some problems in energy consumption and in safety. If a motor is operating at a lower voltage than it was designed for, it is probably using more amperage than was intended and is causing unnecessary losses in transmission lines. If the wires are too small for the load, line losses can be large, and fi re hazards increase significantly. Other problems that can create unnecessary energy loss are voltage imbalance in three-phase motors and leaks from voltage sources to ground. The problems and solutions for the electrical systems are shown in **Table 29**[46].

Table 29 Electrical system - Problems and solutions

Component	Problem	Initial Maintenance Action
Transformer	Leaking oil	Have electric company check at once
	Not ventilated	Install ventilation or provide for natural ventilation
	Dirt or grease in transformer & control room	Install air filtering system to insure clean contacts

Component	Problem	Initial Maintenance Action
	Water on control room floor	Install drainage or stop leaks into control room
Contact	Burned spots	Indicates shorting; repair immediately
	Frayed wire	May cause shorting; use tape to secure frayed ends
Switch	Sound of arcing, lights flicker	Replace
Motors	Noisy	Check bearings
	Too-hot	Check voltage on both legs of three-phase input
	Vibrates	Check mounting

5.4.4. Best operating and maintenance practices for pumps

The characteristics of oversized pump and its description is presented in **Table 30**.

Table 30 Oversized pump and its description

Characteristics of Oversized Pump	Description
Excessive flow noise	Oversized pumps cause flow-induced pipe vibrations, resulting in excessive noise and increased damage to pipework (including flanged connections, welds and piping supports)
Highly throttled flow control valves	Pumps tend to remain in more restrictive positions in systems with oversized pumps; this increases backpressure, further decreasing efficiency
Frequent replacement of bearings and seals	Increased backpressures from increased flow rates creates high radial and thrust bearing loads as well as high pressures on packing glands and mechanical seals
Heavy use of bypass lines	A system that heavily uses bypass lines indicates that the system has either oversized pumps, is not balancing properly, or both
Intermittent pump operation	Pumps being used for purposes such as filling or emptying tanks that run very intermittently indicate oversizing and hence suffer increased start/stop inefficiencies and wear, as well as increased piping friction

Pump wear and maintenance Effective, regular pump maintenance keeps pumps operating efficiently and allows for early detection of problems in time to schedule repairs and to avoid early pump failures. Regular maintenance avoids losses in efficiency and capacity, which can occur long before a pump fails. The main cause of wear and corrosion is high concentrations of particulates and low pH values. Wear can create a drop in wire to water efficiency of unmaintained pumps by around 10–12.5%. Much of the wear occurs in the first few years, until clearances become similar in magnitude to the abrading particulates.

Studies indicate that the average pumping efficiency in manufacturing plants can be less than 40%, with 10% of pumps operating below 10% efficiency. Oversized pumps and the use of throttled valves were identified as the two major contributors to the loss of efficiency. Energy savings in pumping systems of between 30% and 50% could be realized through equipment or control system changes. A pump's efficiency can also degrade during normal operation due to wear by as much as 10% to 25% before it is replaced. **Table 31** presents common problems and solutions in pumping system.

Table 31 Pumping - Problems and solutions

Common Problem	Potential Measures to Improve Efficiency
Unnecessary demand on pumping system	Reduce demand on system
Oversized pumps	Select pump that operates near to BEP

Common Problem	Potential Measures to Improve Efficiency
	Change impeller Trim impeller Fit multiple-speed pump Use multiple-pump arrangements Fit lower speed pump/motor
Pump wear	Pump maintenance
Less efficient impeller	Change impeller
Inefficient pump throttling controls	As for oversized pumps Fit adjustable or variable-speed drive
Inefficient piping configuration	Change piping inefficiencies
Oversized motor	Change motor
Inefficient motor	Change to high-efficiency motor
Lack of monitoring and/or documentation	Install monitoring and conduct survey

The summary of best practices for pumping system are as follows:

- Ensure adequate NPSH at site of installation.
- Ensure availability of basic instruments at pumps like pressure gauges, flow meters.
- Operate pumps near best efficiency point.
- Modify pumping system and pumps losses to minimize throttling.
- Adapt to wide load variation with variable speed drives or sequence control of multiple units.
- Stop running multiple pumps -add an auto-start for an on-line spare or add a booster pump in the problem area.
- Use booster pumps for small loads requiring higher pressures.
- Increase fluid temperature to reduce pumping rates in case of heat exchangers.
- Repair seals and packing to minimize water loss by dripping
- Balance the system flows and reduce pump power requirements
- Avoid pumping head with a free return (gravity): Use siphone effect to advantage
- Conduct water balance consumption
- Avoid cooling water re-circulation in DG sets, air compressors, refrigeration systems, cooling towers feed water pumps, condenser pumps and process pumps.
- In multiple pump operations, carefully the operation of pumps to avoid throttling
- Provide booster pumps for few areas of higher head
- Replace od pumps by energy efficient pumps
- In case of over designed pump, provide variable speed drive, or downsize/replace impeller or replace with correct sized pump for efficient operation
- Optimize number of stages in multi-stage pump in case of head margins
- Reduce system resistance by pressure drop assessment and pipe size optimization

5.4.5. Best operating and maintenance practices for motors

- Loading of motors should be around 75% and under-loaded motor results in lower efficiency and lower power factor.
- The under loaded condition of motors in the plant are mainly because of its operating pattern.
- Inspecting motors regularly for wear in bearings and housings (to reduce frictional losses) and for dirt/dust in motor ventilating ducts (to ensure proper heat dissipation).
- Checking load conditions to ensure that the motor is not over-loaded or under-loaded. A change in motor load from the last test indicates a change in the driven load, the cause of which should be understood.

- Manufacturers generally provide recommendations for how and when to lubricate motors. Inadequate lubrication can lead to problems. Over lubrication can also create problems, e.g. excess oil or grease from the motor bearings can enter the motor and saturate the motor insulation, causing premature failure or creating a fire risk.
- Checking periodically for proper alignment of the motor and the driven equipment.
- Improper alignment can cause shafts and bearings to wear quickly, resulting in damage to both the motor and the driven equipment.
- Ensuring that supply wiring and terminal box are properly sized and installed. Inspect regularly the connections at the motor and starter to be sure that they are clean and tight.
- Ambient conditions can also have a detrimental effect on motor performance. For example, excessively high temperatures, high dust loading, corrosive atmosphere, and humidity can impair insulation properties; mechanical stresses due to load cycling can lead to misalignment. However, with adequate care, motor performance can be maintained.
- Rewinding can affect a number of factors that contribute to deteriorate motor efficiency.

5.4.6. Best operating and maintenance practices for compressed air system

- Ensure air intake to compressor is not warm and humid by locating compressors in well ventilated area or by drawing cold air from outside. Every 4°C rise in air inlet temperature will increase power consumption by 1 percent
- Clean air-inlet filters regularly. Compressor efficiency will be reduced by 2 percent for every 250 mm WC pressure drop across the filter.
- Keep compressor valves in good condition by removing and inspecting once every six months. Worn-out valves can reduce compressor efficiency by as much as 50 percent.
- Install manometers across the filter and monitor the pressure drop as a guide to replacement of element.
- Minimize low-load compressor operation; if air demand is less than 50 percent of compressor capacity, consider change over to a smaller compressor or reduce compressor speed appropriately (by reducing motor pulley size) in case of belt driven compressors.
- Consider the use of regenerative air dryers, which uses the heat of compressed air to remove moisture.
- Fouled inter-coolers reduce compressor efficiency & cause more water condensation in air receivers & distribution lines resulting in increased corrosion. Periodic cleaning of intercoolers must be ensured.
- Compressor free air delivery test (FAD) must be done periodically to check the present operating capacity against its design capacity and corrective steps must be taken if required.
- If more than one compressor is feeding to a common header, compressors must be operated in such a way that only one small compressor should handle the load variations whereas other compressors will operate at full load.
- The possibility of heat recovery from hot compressed air to generate hot air or water for process application must be economically analyzed in case of large compressors.
- Consideration should be given to two-stage or multistage compressor as it consumes less power for the same air output than a single stage compressor.
- If pressure requirements for processes are widely different (e.g. 3 bar to 7 bar), it is advisable to have two separate compressed air systems.
- Reduce compressor delivery pressure, wherever possible, to save energy.
- Provide extra air receivers at points of high cyclic-air demand which permits operation without extra compressor capacity.
- Retrofit with variable speed drives in big compressors, say over 100 kW, to eliminate the `unloaded' running condition altogether.
- Keep the minimum possible range between load and unload pressure settings. • Automatic timer controlled drain traps wastes compressed air every time the valve opens. So frequency of drainage should be optimized.

- Check air compressor logs regularly for abnormal readings, especially motor current cooling water flow and temperature, inter-stage and discharge pressures and temperatures and compressor load-cycle.
- Compressed air leakage of 40 – 50 percent is not uncommon. Carry out periodic leak tests to estimate the quantity of leakage.
- Install equipment interlocked solenoid cut-off valves in the air system so that air supply to a machine can be switched off when not in use.
- Present energy prices justify liberal designs of pipeline sizes to reduce pressure drops.
- Compressed air piping layout should be made preferably as a ring main to provide desired pressures for all users.
- A smaller dedicated compressor can be installed at load point, located far off from the central compressor house, instead of supplying air through lengthy pipelines.
- All pneumatic equipment should be properly lubricated, which will reduce friction, prevent wear of seals and other rubber parts thus preventing energy wastage due to excessive air consumption or leakage.
- Misuse of compressed air such as for body cleaning, agitation, general floor cleaning, and other similar applications must be discouraged in order to save compressed air and energy.
- Pneumatic equipment should not be operated above the recommended operating pressure as this not only wastes energy bus can also lead to excessive wear of equipment's components which leads to further energy wastage.
- Pneumatic transport can be replaced by mechanical system as the former consumed about 8 times more energy. Highest possibility of energy savings is by reducing compressed air use.
- Pneumatic tools such as drill and grinders consume about 20 times more energy than motor driven tools. Hence they have to be used efficiently. Wherever possible, they should be replaced with electrically operated tools.
- Where possible welding is a good practice and should be preferred over threaded connections.
- On account of high pressure drop, ball or plug or gate valves are preferable over globe valves in compressed air lines.

5.4.7. Best operating and maintenance practices for lighting system

- Light levels decrease over time because of aging lamps and dirt on fixtures, lamps and room surfaces. Together, these factors can reduce illumination by 50 percent or more, while lights continue draw in full power.
- Regular maintenance is essential to ensure that facilities receive the desired quantity and quality of light, as well as energy efficiency, from their lighting systems. Periodic maintenance can produce a range of benefits, including a brighter and cleaner workplace, a higher level of security, and enhanced productivity.
- The basic maintenance includes cleaning of lamps and fixtures, cleaning and repainting interiors and re-lamping. Keep light-reflecting surfaces and lenses clean in order to maintain designed light levels (**Table 32**).

Table 32 Recommended illumination level

Area	Recommended Average Lux level
General factory area	
Canteens	150
Cloakrooms, change rooms, storages	100
Entrances	100
Factory outdoor areas	
Stockyards, main entrance,	20
Internal roads, exit roads, car parks	20

Area	Recommended Average Lux level
Assemble shop	
Rough work e.g. frame assembly	150
Medium work e.g. machined parts	300
Fine work e.g. Electronics assembly	700
Very fine work e.g. instrumentation assembly	1500
Boiler house	
Coal and ash handling	100
Boiler room	100
Outdoor plant	20
Control rooms	300
Inspection shops	
Rough work e.g. counting	150
Medium work e.g. sub-assembly	300
Fine work e.g. calibration and precision work	700
Very fine work e.g. critical parts	1500
Laboratories and test rooms	450
Office work space	300

- Workers should take care not to touch the envelope of halogen bulbs because doing so leaves skin oils on the glass surface. As these bulbs heat and cool, the oils cause uneven stress, leading to glass cracking and shorter lamp life.

Tips for cleaning fixtures:

- Clean lighting fixtures whenever lamps are replaced. In areas where doors allow outside air or filtering is not adequate, clean at least twice a year.
- Wipe plastic lenses with damp, not dry cloth (a mild detergent may be needed). Small cell louver panels, including parabolic wedge louvers, should be removed and dipped in mild detergent solution, then air-dried.
- Do not wipe luminaire or lamps while fixture is energized.
- Line voltage should be checked at the fixture and compared with the ballast rating to be sure it is within the prescribed limits, so as to prevent lamps premature failure due to flickering caused by voltage fluctuation, hence if voltage controllers/stabilizers are present then its maintenance should also be done periodically.
- Replacement of old conventional magnetic ballast with new electronic ballast also reduces maintenance part of ballast repairing.
- To avoid damage to ballasts, lamps are replaced when it ceases operation unexpectedly, failed to light up after turning it on.
- Lamps should be replaced when they reach 70%-80% of their rated life. Your lamp supplier has additional information available regarding lamp maintenance procedures.
- Bulbs should be replaced not only when they break, but on a schedule according to how the brightness of the lamp decays over time. Some bulbs lose over a third of their initial brightness over a few years.
- Glass strips, running continuously across the breadth of the roof at regular intervals, can provide uniform lighting on industrial shop floors and storage bays, also maximum usage of daylights should be done in industries/factories by using transparent/translucent roofing sheets so as to minimize usage of electrical lighting in daytime.

A representative inspection intervals for various equipment/system used in industries is presented in **Table 33**, it will help industries to develop their own procedures.

Table 33 Preventive maintenance actions

Area	Frequency
Airlines	
1. Check for leaks	
Blowers	Annually
1. Inspect belts for tension and alignment	
2. Inspect pulley wheels	
3. Inspect for dirt and grease	
Boilers	
1. Check temperature and pressure	Daily
2. Clean tubes and other heating surfaces	As needed
3. Check water gauge glass	Daily
4. Remove scale	Annually
5. Perform flue-gas analysis	Monthly
6. Calibrate controls	Annually
Chillers	Annually
1. Clean condenser and oil cooler	
2. Calibrate controls	
3. Check electrical connections	
4. Inspect valves and bearings	
Condensate return system	
1. Check valves, pumps, and lines	Annually
Cooling coils	
1. Brush and wash with soap	Quarterly or when needed
2. Clean drip pan drain	When needed
Compressors	
1. Check oil levels	Monthly
2. Check wiring	Annually
3. Visual check for leaks	Monthly
4. Log oil temperature and pressure	Monthly
5. Remove rust with wire brush	Annually
6. Replace all drive belts	Annually
Condenser	
1. Clean fan	Annually
2. Brush off coil	Monthly
Controls	
1. Calibrate thermostats	Semiannually
2. Get professional inspection of control system	According to equipment specifications
3. Check gauges to see that readings are in correct range	Monthly
4. Examine control tubing for leaks	Monthly
Cooling towers	
1. Inspect for clogging and unusual noise	Daily

Area	Frequency
2. Check gear reducer oil	Level—weekly. For sludge and water— monthly
3. Inspect for leakage	Semiannually
4. Tighten loose bolts	Semiannually
5. Clean suction screen	Weekly
Dampers	
1. Check closure	Every 6 weeks
2. Clean with brush	Semiannually
Ductwork	Semiannually
1. Inspect and refasten loose insulation	
2. Check and repair leaks	
3. Inspect for crushed or punctured ducts; repair	
Electrical system	
1. Inspect equipment for frayed or burned wiring	Semiannually
2. Perform electrical load analysis	Whenever major equipment changes occur, or every 2 years
Fans	
1. Check fan blades and clean if necessary	Semiannually
2. Check fan belts for proper tension and wear	Monthly
3. Check pulleys for wear and alignment	Semiannually
4. Check for drive noise, loose belts, and excessive vibration	Semiannually
Faucets	
1. Check for leaks; replace washers if needed	Annually
Filters, air	
1. Replace	When dirty, or monthly
2. Check for gaps around filters	When replacing
3. Inspect electrical power equipment	Monthly
Filter, oil	
1. Clean and oil	Whenever compressor oil is changed
Gauges	
1. Check calibration	Annually
2. Check readings	As needed
Grillwork	
1. Remove dirt, grease, bugs	Monthly
2. Remove obstructions from in front of grill	Monthly
3. Check air direction	Monthly
4. Recaulk seams	As required
Leaks	
1. Check for refrigerant leaks	Annually
Lights, inside	
1. Perform group re lamping	As required
2. Perform survey of lighting in actual use	Semiannually
3. Clean luminaires	Office area: every 6 months; laboratories: every 2 months; maintenance shops: every 6 months; heavy manufacturing areas: every 3 months; warehouses: every 12 months

Area	Frequency
4. Replace flickering lights	Immediately
Motors	
1. Lubricate bearings	When needed
2. Check alignment	Semiannually
3. Check mountings	Semiannually
Ovens	Semiannually
1. Check insulation	
2. Check controls	Annually
3. Check firebrick and insulation	Annually
Piping	
1. Check mountings	Annually
2. Check for leaks	Semiannually
Pumps	
1. Check lubrication	Monthly
2. Examine for leaks	Semiannually
Steam traps, high pressure (250 psig or more)	
1. Test	Daily-weekly
Steam traps, medium pressure (30-250 psig)	
1. Test	Weekly-monthly
Steam traps, low pressure	
1. Test	Monthly-annually
Steam traps, all	
1. Take apart and check for dirt and corrosion	If test shows problems
Thermostats	
1. Check calibration	Annually
Time clocks	
1. Reset	After every power outage
2. Check and clean	Annually
Transformers	
1. Inspect gauges and record readings	Monthly
2. Remove debris	Monthly
3. Sample and test dielectric	Annually
4. Remove cover and check for water	Every 10 years
Walls and windows	
1. Check for air infiltration	Semi-annually
2. Clean	Regularly, when dirty

5.5. Best Operating Practice (BOP) case studies

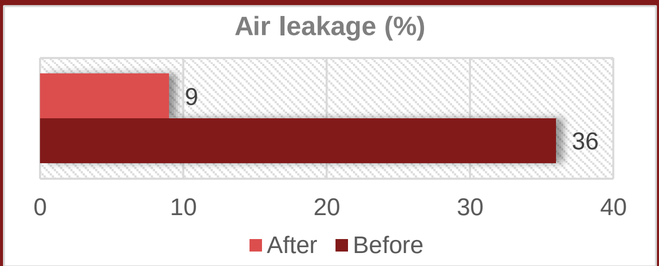
Box 21: Compressed air leakage arresting

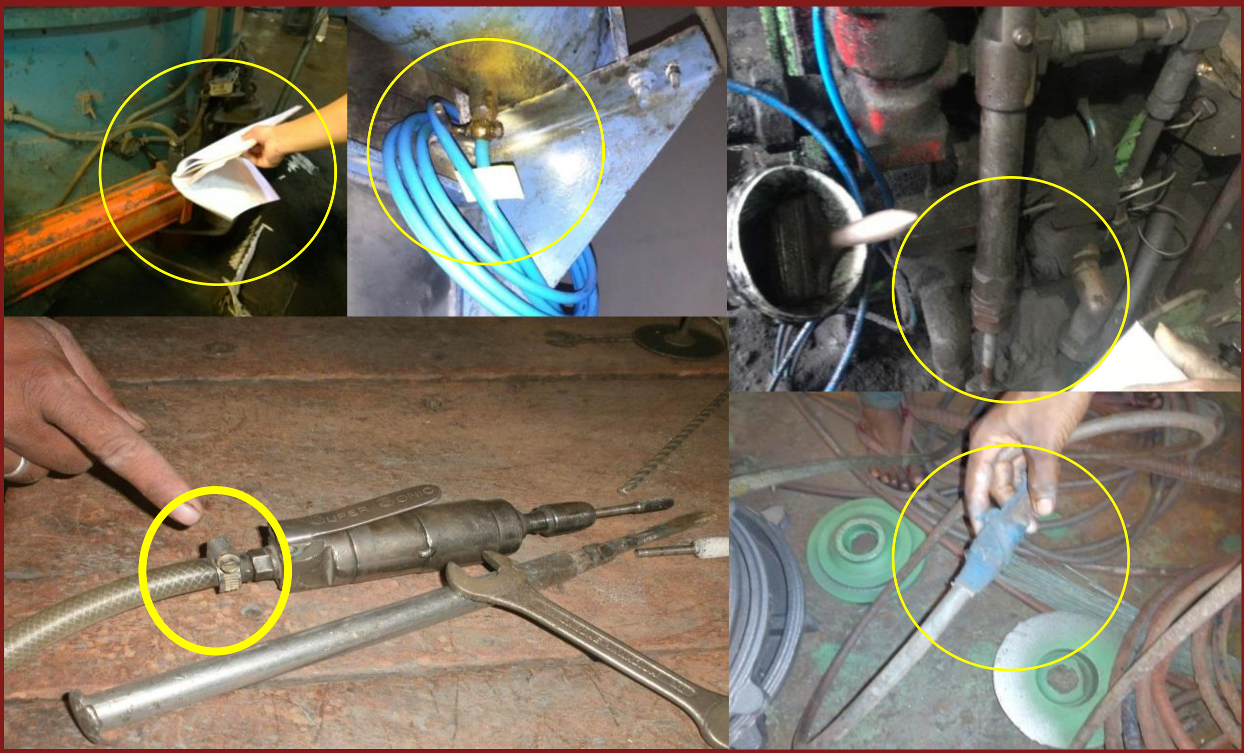
Baseline scenario: A metal processing industry has a 250 cfm air compressor installed to meet its compressed air needs. A capacity test reveal that the actual generation from air compressor was 241 cfm. The loading and unloading profile of air compressor was studied for 24 hours to arrive at actual compressed air need of the plant. A leakage test revealed 36% of compressed air generated was leaked in to air through faulty valves, piping and joints.

Proposed solution: A thorough leakages test was conducted to identify major leakages points and they were arrested. The compressed air system leakage test methodology was provided to plant management and the maintenance team made the leakage test a weekly regular practice (part of SOP).

Savings:

- 21 leakages points identified
- Leakage - 36% of FAD
- Annual electricity saving - 36,880 kWh
- Annual monetary savings – US $ 4,550
- Simple payback – 1 months
- Energy saving - 12.3%
- GHG reduction potential: 30 t CO_2/year





6 Water management and efficiency improvement

6. Water Management

Water efficiency means using improved technologies and practices that deliver equal or better service with less water. For example, the use of low flow faucet aerators can be more powerful than no aerators for washing hands. ***Water conservation*** has been associated with curtailment of water use and doing less with less water, typically during a water shortage, such as a drought.

For example, minimizing lawn watering and automobile washing in order to conserve water. Water conservation also includes day-today demand management to better manage how and when water is used, so it is common to hear the words water conservation used synonymously with water efficiency.[47]

Change behavior vs. Equipment[47]

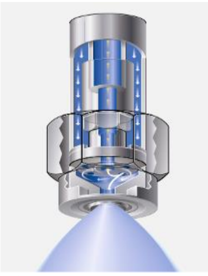
Equipment changes may be viewed as a permanent fix to achieve water efficiency. Changing employee behaviors, such as an operating procedure, may be viewed as a quick and inexpensive way to achieve similar savings without up-front capital expense. In reality, both the technical and human side of water management issues must be addressed. Consistent training and awareness in combination with proper tools and equipment will achieve more permanent water savings.

This section of the manual presents an overview of the various practical water efficient technologies, retrofits and leading operating practices that can be implemented across industries for effective water management.

6.1. Water Efficiency Technologies

6.1.1. Spray and jet nozzles

Spray and jet nozzles are precision devices that facilitate dispersion of liquid (water and gas) into a spray. Across industries spraying techniques aid in the accomplishment of numerous tasks. Nozzle and nozzle systems play a crucial role in all production stages in terms of process optimization aimed at increasing quality and perfecting production.



Source: Lechler

The choice of the appropriate spray and jet nozzles will depend on the industry and process related specific requirements (flow, spraying technique and size of dispersed fluid droplets). These include pneumatic atomizing nozzles, hollow cone spray, full cone spray, flat fan spray, solid stream nozzle (primary-jet), air nozzles and tank cleaning nozzles. The typical application areas of nozzle systems in industries are presented in **Table 34**[48]. Case example is presented in **Box 22**[49].

Table 34 Industry application of nozzle systems

Industry*	Application area
Beverages	• **Disinfection and hygiene**: Typically used for disinfecting hand, work equipment, sole and boot and rooms • **Product treatment**: Tank cleaning, product cooling (ham, sausage etc.), can cleaning, coating processes (e.g. vitamin spraying or spraying of low viscosity sugar solutions), belt cooling (spraying the underside of conveyor belts with water or coolant), bottle and barrel cleaning, crate washing

[47] *Water Efficiency Manual by North Carolina Department of Environment and Natural Resources*
[48] *https://www.lechler.com/de-en/industrysectors/*
[49] *Spraying systems Co: Change the way you spray to maximize water conservation*

Industry*	Application area
	• **Filling and packing**: Sterilization of PET bottles, filler cleaning, belt lubrication, pasteurization of preservative products
Cement	• **Gas cooling**: Precision cooling and conditioning of hot flue gases for safe and efficient operation of downstream plant components • **Clinker cooling**: Injection spray into the clinker for cooling gas and its volume thereby reducing operating costs and future investment costs for a large filter
Fertilizer	• Typical areas of use include heat exchanger cooling, de-superheating, granulation, pelletizer, tank cleaning, sulfuric acid regeneration, fractionation etc.
Mining	• **Process**: Usage areas includes: Mineral processing, dust suppression, slurry transport, ablution • **Domestic**: As mines as located in remote areas, mine site usually has a village for employee residence hence has a substantial domestic water usage

* *These areas of application are indicative and may vary from industry to industry and depending the plant specific operating conditions.*

Box 22: Case Example - Nozzle spray system

Baseline scenario: A chemical processing plant was using around 1,050 litres of 150°C water to clean an average size, 1,500 litres tote (bulk containers for storing chemicals). The plant was cleaning around 30,000 totes per year and each cleaning cycle was approximately 30 minutes.

Proposed solution: The company realized that the baseline cleaning system was cost-prohibitive and decided to venture out for spray and jet technologies that could ideally provide some efficiency improvement and water savings. A motorized tank washer with jet spray technology was installed. The new system uses less water and cleans the tote in lesser time.

Savings:

- Each tote is cleaned with ~480 litres of hot water
- Annual hot water savings of ~16,000 kL/year
- Annual cost savings due to water consumption reduction of ~US$ 28,000

6.1.2. Reverse Osmosis (RO) system

Treatment of wastewater is of fundamental importance for any industry due to the emerging regulations around water discharge. RO technologies use filters and membranes to remove impurities (dissolved solids and bacteria) from water. In industries, RO system is used to improve the quality of water which further circulated to various processes.

RO systems generally have a recovery rate (ratio of purified water to feed water) of 50 to 75%, meaning that 25 to 50% of the incoming water remains as residual and is rejected from the system.[50] The recovery rate can be increased by increasing the number of stages of membrane pressure vessels, allowing higher pressures to be achieved in order to more effectively overcome natural osmosis. In some cases, it could be possible by adjusting the size of reject flow controllers or modifying ancillary components (e.g. storage tanks) of the RO system.

The reject water from the system is less pure than source water and can be used for other applications if the sanitary conditions are maintained for storage and transfer. Typical end-uses of RO reject water include: toilet and urinal flushing; cooling tower make-up water; above-ground irrigation; make-up water for decorative ponds, fountains, and waterfalls. Case example is presented in **Box 23** [51].

[50] *US EPA, WaterSense at Work: Best Management Practices for Commercial and Institutional Facilities*
[51] *http://www.mcilvainecompany.com/Decision_Tree/subscriber/Tree/DescriptionTextLinks/Beer.pdf*

Box 23: Case Example - Reverse Osmosis system

Baseline scenario: A beer brewery used ion exchanger technique for desalinization and treatment of water used for producing beers. The increasing regulations around water quality for beer production and quality of the end product pushed the company to look for a technology upgrade.

Proposed solution: The company decided to invest in a RO plant to improve water quality used for beer production as well as to ensure constant availability of water through the day. This plant physically desalinizes the well water by pressurising it with a semi-permeable membrane, thus producing pure and sterile water with hardly any salt. In addition, the plant was fitted with variable frequency pumps to save operating costs and increase the lifetime of the RO membrane

Savings:

- Source water production from the plant is around 50 m³/h
- With the help of the variable frequency pumps, electricity production reduced by 30%

6.1.3. VapourGuard for water storage tanks and reservoirs

As climate change is becoming more prevalent, the country is prone to erratic rainfall thereby resulting in droughts. Due to this, water harvesting is looked as a potential adaptation measure by various industries. Open ponds and reservoirs are practical solutions being implemented across industries to conserve water. With Zimbabwe being a semi-arid region, the rate of evaporation ranges from 2.9 – 8.6 mm/day leading to loss of stored water.[52] To address this, VapourGuard[53] cover can be utilized to cover open ponds and wells. The cover floats on the water surface to prevent evaporation and preserve water quality. The cover can be custom manufactured to fit the dam or reservoir based on the size of the structure.

Made from the GeoBubble membrane, this cover collects rainfall as it is a floating cover, partially perforated to absorb water from rain into the underlying stored water body but will not release water into the atmosphere. The cover rises and falls with changes in the water level. The light top surface of the VapourGuard Geomembrane material is designed to reflect the sun's heat away from the water surface area, preventing heat build-up. The dark underside of the geomembrane material is designed to prevent light penetrating the surface, inhibiting algae growth and bacteria in the contained water. The VapourGuard cover reduces water contamination by virtually sealing the surface area, air-born debris is substantially reduced which in turn reduces water contamination.

Box 24: Case Example - VapourGuard

Baseline scenario: A mining facility implemented water-harvesting system through rainwater harvesting technique. The water collected is diverted and stored in open reservoirs. Despite the increase in the storage capacity, there was significant evaporation loss of around 3,216 m³/year.

Proposed solution: The company decided to install VapourGuard covers across 3 reservoirs that had a collective surface area of 1,728 m³/year.

Savings:

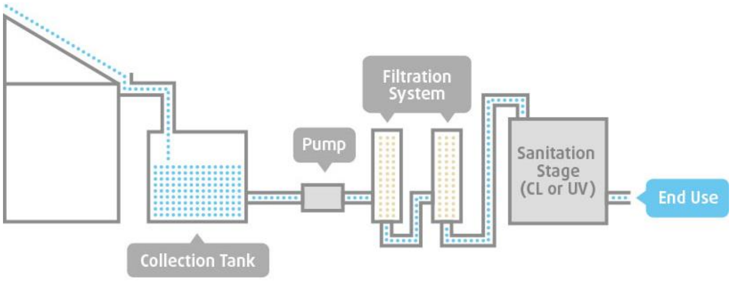
- Evaporation loss reduced to 64.33 m³/year
- Annual water saving of ~3,200 m³/year

[52] *https://www.omicsonline.org/open-access/exploring-estimation-of-evaporation-in-dry-climates-using-a-class-a-evaporation-pan-2168-9768.1000109.php?aid=19091*
[53] *http://www.vapourguard.com/english/*

6.1.4. Rainwater harvesting

Industrial facilities with large areas of impervious cover can capture rainfall for use in non-potable and potable (post treatment through RO) applications. Rainwater that runs-off of rooftops is typically of high quality, making it suitable for many end uses. In most facilities, it is used to supplement or replace irrigation water with little treatment or filtering. As a rule of thumb, it can be assumed that around 2.35 litre of water can be collected per sq. foot of collection surface area per inch of rainfall. Typical rainwater system installers will assume 80% capture efficiency since some of the water is lost due to evaporation, splashing or other means.[50]

Rainwater from roofs and non-roof areas can act as a good source of water for irrigation and other process provided they could be captured, treated and stored. Generally, this collected water can be captured and distributed from onsite features, such as berms, swales, or rain gardens, or can be diverted to a long-term storage detention pond and reservoirs, where the water can be pumped for landscape irrigation or other uses. In some cases, the quality of water might be poor since it picks up pollutants as it travels across the landscape of the facility. It is thus essential to consider water quality needs of the end use or provide appropriate treatment before using.



Source: CleanWater, Guide to Rainwater Harvesting and Treatment

Box 25: Case Example - Rainwater harvesting

Baseline scenario: A mining facility was utilizing water from nearby dams to its plant resulting in excessive water and energy consumption. Since the average rainfall in the region was around 600 mm, the facility required a mechanism which could reduce water consumption to avoid any risk to its operations.

Proposed solution: The facility decided to implement a rainwater harvesting system to reduce the cost of pumping water from the dam site to plant and also reduce the overall water consumption marginally. The system designed was capable of harvesting around 8,500 m^3/year at a run-off efficiency of 90%.

Savings:

- Rainwater harvesting potential of ~8,500 m^3/year
- Annual water savings of ~US$ 450/year
- Annual energy saving from reduced pumping of US$ 4,800 kWh/year

6.1.5. Pigging system for waste reduction

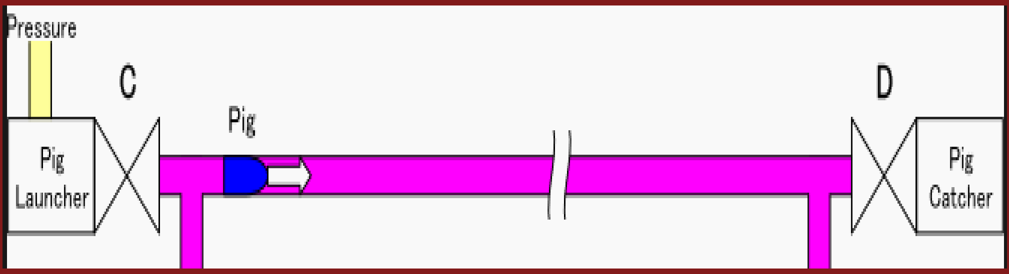
Pigging technologies have found widespread applications in various industries to reclaim liquids from pipelines and tubing, reduce product waste and improve the efficiency of the manufacturing and production processes. It is a technology that uses specialist projectiles to recover rather than waste, residual liquid in pipelines or industrial tubing. It has progressed from basic equipment used to clean oil pipes, to advanced, fully automated industrial product recovery and liquid transfer technology used today.

In its simplest form, pigs which are slightly larger in diameter than the pipe or tube, is propelled manually (at times) but more commonly automatically. Usually compressed air, CO_2, N_2, clean water or even the next product is used to provide the pressure to propel the pigs. Instead of being flushed to drain, waste treatment or collection areas, the liquid residue in the pipe is recovered: pushed by the pig and forced to the destination filler or tank to continue processing along with the rest of the product. The system includes components such as pig launchers, receivers, detectors, storage, housings, propellant sources, PLCs, HMI's, control software, and various valves, supports and fittings. These systems can be either retrofitted to an existing process or designed based on the requirement.

Box 26: Case Example - Pigging system

Baseline scenario: A beverage manufacturer was using line assembly process to fill soft drinks into the cans/bottles. During cleaning, product was discharged to drain resulting in high effluent charges and lower product recovery.

Proposed solution: The manufacturer decided to implement a Fully Automatic Pigging System (2" diameter size) to deliver the product from any of four tanks to the filling machine. The design incorporated pigging from the last tank, past all other tanks to accommodate the flexibility of using any one of the four tanks to serve the line. Syrup is pigged into a balance tank which has high and low level sensors. Should the high level sensor activate during pigging the propellant behind the Pig, nitrogen in this case, is vented behind it. Once the low level signal is received the propellant is opened again to allow the pig to proceed (gently) to the balance tank.



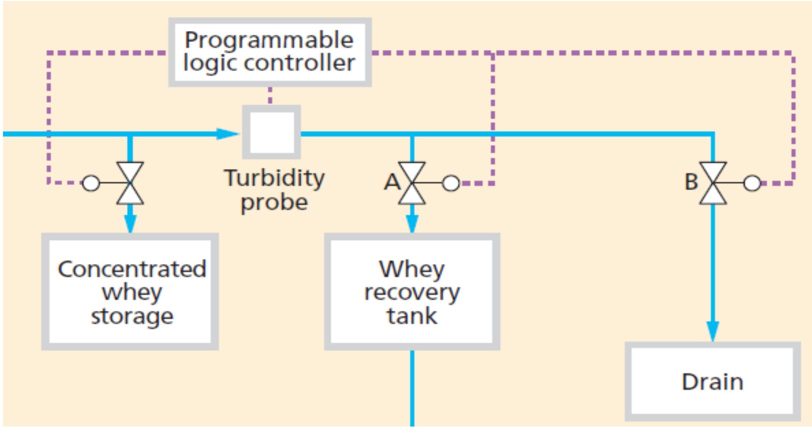
Savings:

- Product savings, improved process efficiency and waste reduction through highly effective product recovery
- 4% improvement in product yield equivalent to 48,000 extra cans per week

6.1.6. Turbidity probes

Turbidity is a property that is a result of particles of solid matter being suspended in water, rather than dissolved into it. If water is turbid it appears to be cloudy, so is a visual guide to water quality. Turbidity water testing is an important part of water quality maintenance. Increased levels of turbidity raises water temperatures, because heat is absorbed by the suspended particles. Sudden changes in turbidity may be an indication of the emergence of a new pollution source, or with drinking water there may be an issue in the treatment process.[54]

Turbidity probes are devices that are fitted in pipework to detect product-water interfaces during rinsing operations. A turbidity probe works by sending a light beam into the water to be tested. This light will then be scattered by any suspended particles. The amount of light reflected is used to determine the particle density within the water. The signal can be used to control valves which are connected to the cleaning equipment. For instance, in case of more turbid water, a dishwasher will increase water cycles and would recycle less water.



Source: Case Study, US Environment Protection Agency

[54] https://www.aquaread.com/need-help/what-are-you-measuring/turbidity/

Box 27: Case Example - Turbidity probes

Baseline scenario: A creamery manufacturing firm wanted to reduce the effluent strength during the time when the evaporator was cleansed.

Proposed solution: For managing this issue, the company installed turbidity probes in the whey processing line at its North Devon site. The probe was connected to a PLC through which effluent strength was monitored and water recycling rate was improved.

Savings:

- Annual cost savings of ~US$ 21,000

6.1.7. Water free urinals

Water-free urinals or no flush/non-water urinals can reduce water consumption per urinal between 25–45 cubic meters/year. Usually, they are plumbed to a standard drain line (similar to traditional urinals), with sealant liquids acting as vapor trap. The liquids are composed primarily of natural oils. Urine passes through the liquid and goes down the drain. These systems can be installed in any building irrespective of the type of industry. Different types of water urinal and its working is presented in **Figure 19**.

Liquid barrier
- Urine passes through an oil-based sealant
- While the Trap collects debris to help prevent blockages in waste pipes

Valve Barrier
- The pressure of urine flow causes a valve to open
- The valve closes when the flow stops, preventing foul air from the drains being emitted into the washroom
- Complemented by a microbiological block to help prevent build-up of uric acid salts

Microbiological
- Urine touches a block containing microbial spores
- The spores become active bacteria that multiply and 'digest' urine in the trap and waste pipe
- Debris are washed away by sluicing with chemical diluted with warm water

Figure 19 Types of water urinal

Box 28: Case Example - Water free urinal

Baseline scenario: A sports facility with large footfall experienced high urinal use during peak season, around 160 urinal uses per game and was also facing maintenance issues in the form blocks or leaks.

Proposed solution: The building was equipped with 220 water free urinals by eliminating the use of flush valves.

Savings:

- Reduced water consumption by 33 million litres/year
- Reduction in maintenance cost by US$ 22,000 through the elimination of flushing valves and costs associated with clogged urinals and flooded washroom

6.1.8. Graywater recycling

Gray water is wastewater from lavatory sinks, laundries, and bathing. It never contains wastewater from toilets or urinals and excludes wastewater from kitchen sinks. Gray water can be treated and reused for specific onsite applications; however, health and safety concerns must be considered. Graywater recycled are to be consumed within 24 hours of collection, or otherwise properly disposed to avoid bacterial contamination. If treated gray water is used for irrigation, it should only be applied below the surface and should never be used on plants intended for human consumption or sprayed through conventional sprinkler heads where it has the potential to be inhaled.

Gray water is usually coarsely filtered to remove large, suspended solids and, when used for indoor purposes, is usually further sanitized with chemicals such as chlorine. The lowest level of treatment is typically sufficient for subsurface irrigation applications. More intensive treatment is necessary for other applications, including toilet and urinal flushing or above-ground irrigation. Studies have shown in residential applications, graywater systems can reduce indoor water use by 24%, on average. Furthermore, using graywater to meet toilet and laundry requirement can further reduced demand by around 36%.[55] Such applications are suitable for water stressed regions thereby reducing the demand on utilities during drought seasons.

Box 29: Case Example - Graywater recycling

Baseline scenario: A hotel building situated in a water scarce region in the middle east was largely reliant on private water suppliers to fill the water tank ten times every day. The associated costs due to this was mounting and almost 80% of the building's wastewater is in the form of graywater.

Proposed solution: The building was equipped with a graywater recycling plant for capture and reuse within the same premises. The technology deployed treats the water into high quality industrial service water that meets the hygiene requirements of the European Union (EU) Bathing Water Directive. The water is treated without chemical additives in an entirely mechanical-biological process and is subsequently used to flush toilets.

Savings:

- Reduction in total water consumption by 17%

6.1.9. Membrane Filtration

Membrane filtration is a process in which feed water is forced through a semi-permeable barrier layer (membrane) at high pressure to separate specific materials from the solution. The process is classified according to membrane pore size and are commonly referred as microfiltration (MF), ultrafiltration (UF), nano-filtration (NF) and reverse osmosis (RO).

Filtration process: Membrane processes employ a barrier layer that allows molecules to permeate or pass through by 'facilitated diffusion'. The rate of passage depends on the pressure, concentration and temperature of molecules on either side of the membrane, as well as the permeability of the membrane to each type of solution (including size, chemical properties). Typical membrane configurations include spiralwrap, tubular, flat sheets and capillary and are used to separate molecules ranging from 10 µm and smaller depending on the following filtration processes[56].

Various filtration process and its description is presented in **Table 35**.

[55] *http://theconversation.com/a-new-strategy-for-drought-stressed-cities-graywater-recycling-56564*
[56] *http://www.veoliawatertechnologies.co.za/water-technologies/membrane-separation/*

Table 35 Various filtration process

Filtration process	Description	Operating condition	Treatment applications
MF	Removes microorganisms, pathogens and suspended particles larger than 0.1 µm and also acts a filter and disinfectant	Pressure requirement of less than 2 bar	Potable water treatment, industrial and municipal water treatment
UF	With a pore size of between 100 and 2 nm, UF removes particulates and macromolecules from water in potable water and wastewater treatment	Pressure requirement of 1 to 10 bar	Replacement for existing secondary and tertiary filtration, or alongside these processes as an integrated treatment process in water containing high suspended solids
NF	With pore sizes ranging from 2 to 1 nm, NF is used for water softening and removal of organic by-products resulting from earlier disinfectant treatment	Pressure requirement of 3 to 20 bar	Water treatment applications with low total dissolved solids
RO	With pore size of less than 1 nm, RO is used to separate salts, ions and small organic molecules from feed water	Pressure requirement of up to 80 bar	Process water treatment, seawater desalination, brackish water treatment, potable water treatment

Box 30: Case Example - Membrane filtration

Baseline scenario: A beverage manufacturing company was using a water treatment system for soft drinks production which included filtration, reverse osmosis and softening.

Proposed solution: The company realized that the baseline treatment system required further optimization to meet the rising standards and water requirements for production of quality products. Moreover in line with its goal of improving water-use efficiency by 20%, it was inevitably decided to implement a reclamation system treating backwash water and first permeate of reverse osmosis.

The existing water treatment plant consisted of multimedia filtration, activated carbon filtration and either reverse osmosis and nanofiltration for process water applications or softening for utility feed water applications. A new treatment line was added to extend the capacity of the plant and a reclamation system was implemented to further reduce the raw water quantity in the process. The filtered and reclaimed water is then reused as raw water.

Savings:

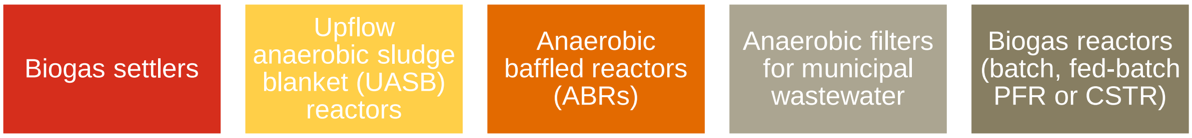
- High water quality standard
- High water-use efficiency
- Reduction in water footprint by 200m^3/day equivalent to 3% savings in raw water used

6.1.10. Anaerobic water treatment

Anaerobic treatments of wastewater are technological interventions typically implemented for treating more concentrated wastewater. A proven and tested energy efficient technology, anaerobic treatment uses bacteria (biomass) to convert organic pollutants or COD (chemical oxygen demand) into biogas in an oxygen-free environment. Anaerobic micro-organisms (specific to oxygen-free conditions) are selected for their ability to degrade organic matter present in industrial effluents, converting organic pollutants into biogas, a mix of methane (CH_4) and carbon dioxide (CO_2) and a nutrient rich sludge. The energy-rich biogas can then be used for boiler feed and/or combined heat and power (CHP) to produce 'green' electricity and heat whereas the sludge can be composted and used as a fertilizing soil amendment in agriculture.

Source: Veolia

Typical biogas sanitation technologies for the treatment of slurries & solid organic wastes from industry are as follows:[57] Case example is presented in **Box 31**[58].



Box 31: Case Example - Anaerobic water treatment

Baseline scenario: In order to create a state-of-the-art manufacturing facility with the highest sustainability standards, Diageo ventured to invest in a large-scale anaerobic water treatment system. The system was selected since it could assist the company in treating the wastewater to the desired quality as well as generate sufficient renewable energy that could be utilized for the facility's operation.

Proposed solution: The commissioned a dewatering and treatment plant alongside setting up biomass and biogas boilers to generate the required green energy from the waste. The Bioenergy plant generates renewable energy from the spent wash and CIP liquors produced during distillation. The spent grain, a mixture of wheat, malted barley and yeast, is separated from the wash and dewatered to provide fuel for a biomass boiler. The remaining liquid is then treated in a purpose built treatment plant.

The first stage of treatment is an anaerobic process, generating biogas, a by-product, to provide additional fuel to the biomass boiler which provides heat and energy to the distillery. This is followed by an aerobic nitrifying and partial denitrifying membrane bio reactor (MBR), using ultra filtration membranes. The MBR stage is followed by reverse osmosis to produce high quality water for boiler feed and CIP water.

In addition, the plant also converts several thousand tonnes a year of co-products and residues from the distillery into biogas and biomass solids. These are used as inputs for a 7 megawatt electricity plant, producing enough power to supply approx. 10,000 homes.

Savings:

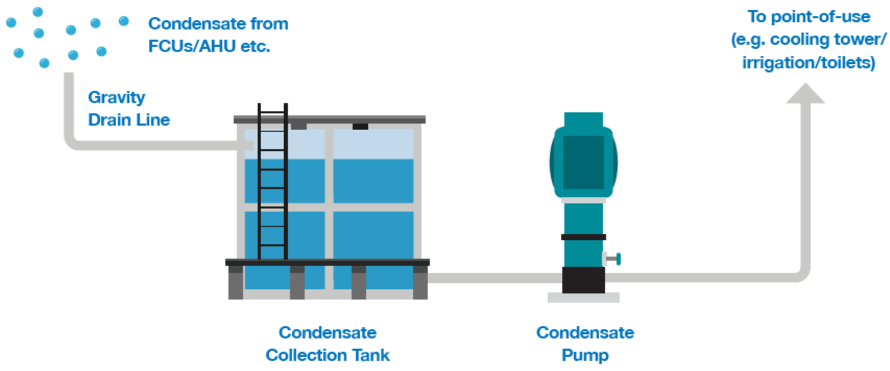
- Generation of around 30 MW of energy, meeting 95% of the facility's energy needs
- Recovery of around 30% of water used in the distilling process
- Emission reductions of around 56,000 tons of CO_2 / annum
- Reduction in total volume of waste water discharged (as measured by BOD) by 55%

[57] *https://sswm.info/content/anaerobic-wastewater-treatment-process*
[58] *https://www.veoliawatertechnologies.co.uk/tech-resource/case-study-diageo-cameronbridge-distillery*

6.2. Water Efficiency Retrofits

6.2.1. HVAC condensate recovery systems

The typical air conditioning system in a commercial building consists of air-handling units (AHUs) that circulate air to indoor spaces to maintain comfort as part of a heating, ventilating, and air conditioning (HVAC) system. Fan coil units (FCUs) are smaller modular versions of AHUs. A make-up air unit (MAU) is a type of air handler that conditions only non-recirculated air, i.e. fresh outside air. As the mixture of air passes through the AHU, it goes through a cooling coil where its temperature drops. Humidity from both outside and return air is removed as condensate. Condensate is generally collected in internal cooling coil drain pans before they are discharged by gravity to the drain pipes on the outside. They can then be collected and reused at various points-of-use in a building. Condensate generation ranges from three to 10 gallons per day per 1,000 square feet of air conditioned space, depending on the type of building and air conditioning system.[35]



Source: PUB, Singapore's National Water Agency: Best Practice Guide in Water Efficiency

Condensate can typically be reused for non-potable areas such as for cooling tower makeup, irrigation, water features, process cooling water and even for toilet flushing reducing cost. Condensate reused for cooling tower makeup is ideal as this water is generally cold with low dissolved mineral content. A typical condensate recovery and reuse system consists of drain pipes, pumping lines, a condensate water collection tank and pumps. Depending on condensate water quality and stipulated requirements, appropriate simple treatment systems can also be included. Case example is presented in **Box 32**[59].

Box 32: Case Example - HVAC condensate recovery

Baseline scenario: An administration building of a leading government institution was draining the condensate generated by the HVAC system into the sewers. The building had 28 floors and was located in the central business district of the city.

Proposed solution: A water audit of the building revealed that installing a condensate recovery system on two of the building's largest air handlers could be a cost-effective option for water recovery and cost savings. In addition, the building already implemented air handler improvements there-by increasing the effectiveness of this technology intervention.

Savings:

- Around 600 kL of water savings
- Reduced water draining into the sewer system
- 15% of the cooling tower water supplied from condensate recovery

6.2.2. Cooling equipment blowdown

Cooling tower bleed-off/blowdown is the flushing of a portion of high mineral concentration cooling tower system water down the drain, while simultaneously replacing it with fresh water. This process dilutes the system

[59] *Case Study: Condensate Recovery System, United States Environment Protection Agency*

water mineral concentrations that steadily increase due to water evaporation. During evaporation of water from cooling equipment, the concentration of TDS builds up causing scaling on equipment surfaces. As a result, some of the water remaining in the cooling equipment must be periodically blown down and replaced with make-up water.

Blowdown rates typically range from 4 to 8% of boiler feed-water flow rate, but can be as high as 10% when makeup water has a high solids content. Although cooling equipment blowdown is typically discharged to the sanitary sewer, it is often of sufficient quality to be used in other onsite applications such as irrigation. It should be noted that the TDS content is significantly higher than that of the original source water, often by two to five times. If the water contains bacterial and other algal content, it has to be treated before usage. Blowdown could be treated through nano-filtration or RO to make it suitable for other uses, particularly for recycling as make-up water for the cooling equipment. Facility managers should carefully assess the possible impacts of using this water on equipment, fixtures, or plants.

A typical cooling tower (500 ton, running 24 hrs day. 365 days per year) will flush over 14.7 Million litres of water down the drain each year. This breaks down to approximately 41,000 litres of waste per day, 1,700 litres per hour, or 28 litres per minute being flushed down the drain from the cooling tower system 24 hours a day, 7 days a week.

Industries with large cooling systems can consider deploying this technique to minimise energy and water costs.

Box 33: Case Example - Boiler blowdown

Baseline scenario: A manufacturing facility with a natural gas fired boiler had a conventional blowdown rate of 8% and at an operating efficiency of 80% and capacity of 108,696 lb/hr. The operations team decided to implement a retrofit system to identify energy and water saving opportunities.

Proposed solution: The existing system was retrofitted with an ‘automatic blowdown control system’ by optimizing surface blowdown through regulated water volume discharge. This system reduced the blowdown to 6%.

Savings:

- Makeup water savings of ~2,300 lb/hr
- Annual water and chemical cost savings of ~US$ 9,000
- Annual cumulative savings (including energy) of ~US$ 70,000

6.2.3. Aerators/flow restrictors

For water conservation in the industry, best way to reduce the use of water is by performing standard tasks with lesser water. To achieve this, aerator taps or flow restrictors are simple solutions, which will allow sufficient quantity of water for routine tasks but lesser consumption. This is considered as an optimal solution for water efficiency improvements in any industry.

Tap aerators are also known as flow regulators. The reduced flow aerator has a pressure-sensitive membrane, a distributor disc with distinctive coarse filter. The membrane reduces the pressure of the water flow, and then the distributor disc increases the speed of the water, drawing in high quantity of air. The membrane has anti clogging screen that filters sediment/debris and it is also scale resistant material. These can be retrofitted with existing taps as well.

Box 34: Case Example - Aerators / Flow restrictors

Baseline scenario: A cable manufacturing company in Southern Africa was using regular taps in the canteen and kitchen areas. These taps had a flow level of 8 to 15 LPM with an annual consumption of around 1,135 m^3/year.

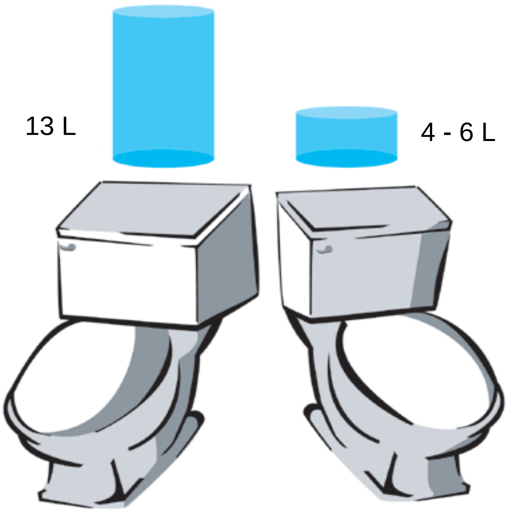
Proposed solution: The company realized that investing towards switching to water efficient fixtures was a possibility. The plant's canteen and kitchen areas were equipped with aerator taps with flow rates of around 2 to 6 LPM.

Savings:

- Reduction in water consumption to ~600 m^3/year
- Reduction in hourly water consumption to ~250 LPH
- Annual savings of ~US$ 300/year

6.2.4. Low flush toilets

Toilets or water closets are found in nearly every industry and its associated facilities. Several types of toilet technologies are installed across industries, including tank-type toilets, flushometer-valve toilets and composting toilets (less used).



The industry has emerged manifold whereby current toilet technologies are performing well while using less water than older models. Most commonly used toilets in industries and commercial facilities are flushometer-valve toilets with a single flush system that typically use 10-13 litres of water per flush.

With the emergence of building codes, standards and benchmarks, there is a push to retrofit existing single flush systems with dual flush systems. These systems reduce flush volume for liquids thereby resulting in energy and operating costs.

When selecting the appropriate low flush system, it is recommended to refer the following international benchmarks:[60]

Efficiency level	Flushing type	Flow rate
High efficiency fixtures and fittings	Full flush	>4 – 4.5 litres
	Reduced flush	>2.5 – 3 litres
Very-high efficiency fixtures and fittings	Full flush	>3.5 – 4 litres
	Reduced flush	>2.5 – 3 litres
Advanced fixtures and fittings	Full flush	3.5 litres or less
	Reduced flush	2.5 litres or less

[60] *USGBC: LEED Building Design + Construction Guideline, PUB: Best Practice Guide in Water Efficiency*

Box 35: Case Example - Low flush toilets

Baseline scenario: A manufacturing company was using regular 13 L/flush single-flush systems in their office spaces. These taps resulted in an annual water consumption of ~1,500 m³/year.

Proposed solution: The company realized that switching to low-flush systems would significantly reduce the water use level across their office spaces. They decide to pursue investments into retrofitting existing single-flush system with double-flush systems, which had a flow rate of 6 L/flush.

Savings:

- Reduction in water consumption to ~750 m³/year
- Annual savings of ~US$ 362/year

6.2.5. Boiler water treatment

For industrial companies using boiler for its facility, it is essential to maintain optimum TDS levels ranging from 1500 – 3500 ppm.[61] As the boiler generates steam impurities in the feed water concentrate in the boiler water. When the concentration of impurities becomes higher, foam is generated and the volume of the boiling water starts to increase. As a result, lower quality wet steam will be generated resulting in efficiency loss. Hence, some type of boiler water treatment system is necessary to ensure an efficiency process and quality steam generation.

A boiler water treatment encompasses several individual technologies essential for both high- (600 psi and higher) and low-pressure (600 psi and lower) boilers. A basic system comprises of technologies related to **filtration/ultrafiltration, ion exchange/softening, membrane processes such as reverse osmosis (RO) and nanofiltration (NF), deaeration/degasification and coagulation/chemical precipitation**. Depending on the impurities present in the water and process requirements, any combination of these technologies might be suited.

How does the system work is shown in **Table 36** and a case example is presented in **Box 36** [62].

Table 36 How does the boiler water treatment system works?

1. Make up water intake	2. Coagulation and chemical precipitation	3. Filtration and ultrafiltration	4. Softening
Water is drawn from the source (raw water, municipal water, municipal treated water, cooling tower, leaked water from boiler)	Post removal of large objects from the raw water, chemicals are added to remove suspended solids and contaminations.	Filtration process to remove sediment, turbidity in order to protect membranes and ion-exchange resins from fouling in the pretreatment process	Treatment of boiler feed water which contains biocarbonates, sulphates, chlorides or nitrates using a softening resin
5. Dealkalization	**6. RO and NF**	**7. Deaeration or degasification**	**8. Distribution**
Dealkalization of the softened water to reduce alkalinity/pH that can cause foaming,	Typical processes for removing harmful impurities down the line that can clog the membranes. This	At this point in the boiler feed water treatment process, any condensate being returned to the system will mix with the treated makeup water and	Post purification of water as per the recommended regulations, the water is fed into the boiler for

[61] *Boiler Blowdown Analysis in an industrial boiler, IOSR Journal of Engineering, 2015, http://www.iosrjen.org/Papers/vol5_issue7%20(part-3)/F05732228.pdf*
[62] *Boiler Feed Case Study, Blue Steel Water Treatment Systems, https://www.bluesteelwater.com/project/boiler-feed-case-study/*

1. Make up water intake	2. Coagulation and chemical precipitation	3. Filtration and ultrafiltration	4. Softening
corrosion, and embrittlement	process is mostly used in high-pressure boilers where concentration of suspended and dissolved solids needs to be extremely low	enter the deaeration or degasification process. Any amount of gasses such as O_2 can be extremely corrosive to boiler equipment and piping when they attach to them, forming oxides and causing rust. Therefore, removing these gases to acceptable levels (nearly 100%) can be imperative to the service life and safety of the boiler system.	steam generation. Condensate return is pumped back into the process to meet up with the pretreated makeup water to cycle through pretreatment again

Box 36: Case Example - Boiler water treatment

Baseline scenario: A food manufacturing plant was equipped with 3 gas-fired boilers with an average load of 8,000 lb/hr and capable of producing steam at 100-110 psi. The facility was experiencing unstable steam pressures, frequent boiler trip-outs and boiler short cycling. An audit revealed excessive energy wastage due to steam venting in the condensate return lines. To address this issue the plant was dumping valuable condensate and utilizing fresh cold makeup water further alleviating the energy wastage. In addition, the water and treatment chemicals lost due to these longstanding systemic issues were another source of waste, all of which added to the daily cost of operating the dairy's boiler system. In addition, excessive energy was being lost during each boiler blowdown because of a lack of a heat recovery system.

Proposed solution: To address the aforesaid issues, system wide improvements were implemented:

- Installation of sensors & transducers to control steam pressure to eliminate boiler trip-outs
- Fixing of steam traps to reduce condensate problems
- Reconfiguration of condensate return/de-aerator tank to eliminate steam venting. This included a spray condenser in an upsized venting system, which not only captured heat that was previously being lost but also enhanced oxygen scavenging to further reduce the chemical demand of the system.
- Installation of a blow down heat recovery system to reduce energy and water consumption

Savings:

- Reduction in system's water requirement of approximately 3,140,000 gallons of treated boiler makeup water / year, 631,000 gallons of domestic water / year and water savings of US$ 30,800/year
- Energy savings of around 10,500 MMBtu/year, for a cost savings of US$ 39,000/annum
- Emissions reduction of 616 tCO_2/year

6.3. Best Operating Practices

This section of the manual presents an overview of the best operating practices for effective water management within an industry. These are built on the existing water management techniques, technology and retrofit interventions described in the previous sections of the manual.

6.3.1. Water accounting

- **Installation of meters and sub-meters** at pipes serving different water usage areas in order to facilitate help you better understand and analyze water use patterns. Metering techniques shall enable industries detect abnormalities in water use.
- **Maintaining regular charting of consumption** at different water use areas is essential for garnering first-hand information on abnormalities

- **Undertaking daily meter readings** (between start of the day and end of the day) shall help you in understanding daily water use for a specific water end use. Over a period of time, such monitoring shall help you to better understand the patterns and breakdown of water usage in your facility.

6.3.2. Leak detection and repair

Identify and repairing leaks and other abnormalities within a facility's system or from processes and equipment is essential for minimizing wastage of significant quantities of water. Reading meters, installing failure abatement technologies, fault-reporting system and audits/inspections are essential best practices to detect leaks. A brief description of the various leak detection techniques are given in **Table 37**.

Table 37 Leak detection techniques

Particular	Description
Reading meters	• Read the facility water meter reading during off-peak hours when all water-using equipment/processes can be turned off • Post this, read meter & then read it again after an hour to check for any changes in the reading. If the reading changes, there could be a possibility of a leak within the facility • Compare monthly water bills to the previous month and to the same month of the previous year, keeping in mind expected seasonal water use increases (e.g., more water in the summer months for cooling)
Failure abatement technologies	• Install leak detection systems on major water-using equipment as these devices are capable of detecting any malfunction (e.g. sudden increase in water flow). The devices can alert the facility team by triggering an alarm, phone call or other method and in some cases, turn off the equipment and in some cases, turn off the equipment
Fault-reporting system	• Implement a fault-reporting system by establishing a clear channel of communication (i.e. call, email, SMS) for users to send fault reports to the facility operations team • Rank reports based on severity level & priorities cases with high potential to continue with water leak • Senior management to track and monitor progress of reports thereby ensure quick resolution of leaks within the stipulated time

Box 37: Case of addressing leaks and unlocking benefits

A brewery implemented a comprehensive utility monitoring system that covers the water supply to the main process areas. Since it was implemented, the system has ensured rapid detection of leaks through continuous monitoring of water use and identification of anomalies in water use patterns from a single valve, to a major equipment. Some of the leak related costs identified through this system include

Fault / leak	Estimated cost (US$/hour)
Hose left on	14
Bottle pasteurizer rinse jets left switched on	14

Fault / leak	Estimated cost (US$/hour)
Leaking ball valve on the bottle pasteurizer	4.10
Leaking ball valve in the keg plant	1.90

6.3.3. Cooling tower management

The cooling system in a typical industrial facility consumes substantial amount of water and energy. Therefore, it is quintessential to have considerable understanding of the water distribution system in order to capably operate and maintain a cooling tower in a water-efficient way. Some of the operating practices that could be adopted are as presented in **Table 38**.

Table 38 Cooling tower water management operating practices

Particular	Description
Reducing uncontrolled losses	*Preventing overflow* • Ensure the float valve on the makeup line can close properly to prevent uncontrolled inflow • Ensure the overflow pipe is installed at the correct level and is not leaking • Ensure that tower water distribution piping is not oversized or too long • Ensure that the operating water levels in multiple tower/cold water basins are equal • Replace ball float valves with solenoid valves that are controlled by electronic level sensors *Reducing water splashing* • Install anti-splash louvres on the tower air intakes • Ensure anti-splash louvers are installed correctly and are not damaged • Ensure the water supply pressure is within manufacturers' limits • Ensure that the fan speed and air flow rates are within manufacturers' limits *Minimizing drift losses* • Install and ensure proper placement of drift eliminators to prevent water droplets and mist from escaping • Ensure the air flow rates are within manufacturers' limits *Arresting leakage* • Conduct periodical inspections to monitor whether there is any leakage at the cooling tower, especially at the pipe connections and joints • Pump gland leakage can be minimised by regular pump maintenance and replacing glands with mechanical sealants
Reducing controlled losses	*Controlling blowdown* • Install conductivity meter to automatically control bleed off of cooling water • Check the ratio of make-up flow to blowdown flow, then check the ratio of conductivity of blowdown water and the make-up water (handheld conductivity meters can be used to determine the relative mineral concentration of the recirculating and make-up water). These ratios should match the target cycles of concentration. If both ratios are not about the same, check the tower for leaks or other unauthorized draw-off • Optimize cycles of concentration (COC) and calibrate conductivity probes • Utilize recycled and treated water from other facility equipment including air-handler condensate, pretreated effluent from processes and high-quality municipal wastewater effluent or recycled water (wherever available) *Increase COC* • Check with the manufacturer / service provider to explore possibilities of optimizing COC of cooling tower so as to reduce blowdown water. It is ideal to operate cooling towers at COC within 7 to 10 for towers using potable water

6.3.4. Optimizing condensate recovery and reuse

The optimization, recovery and reuse of condensate can lead to reduction in piping cost, maximize condensate recovery and reduce the maintenance cost. The potential optimization possibilities are presented in **Table 39**.

Table 39 Optimization possibilities for condensate recovery and reuse

Optimization	Benefit
• Locate AHUs/FCUs along the same vertical stack so that condensate generated can be collected through a vertical drain pipe. In some cases, AHUs/FCUs can be cluster-located in large AHU rooms to minimise cost	Reduction in piping/pumping cost

Optimization	Benefit
• Points of reuse should be centrally located & shouldn't be too high up the facility	
• Since the condensate collection is facilitated by gravity, the condensate water collection tank and associated pumps should be located in close proximity to each other and at the bottom of the vertical condensate collection drain pipe stack. This setup facilitates maximum collection of condensate. • Regular maintenance of the AHUs should be carried out to ensure that the cooling coils inside are clean thereby maximizing heat transfer between coil fins and coil fans	Maximum condensate recovery
• Sizing of condensate tank should be appropriate with a maximum of 1-day storage capacity thereby reducing bacterial growth and lower treatment costs • Pipe gradient of 1.20 : 1.60 shall be adopted in drain pipes so as to avoid slime and bacterial growth[63]	Reduction in maintenance cost

Box 38: Case of water savings through efficient condensate recovery process

A commercial facility implemented an AHU condensate reuse for the cooling tower makeup since its operations began 2010. Through optimum design, operations and maintenance of this system, the facility saved approximately 1,900 m^3 of water per year.

6.3.5. Water efficient cleaning and washing

- Using more water-efficient cleaning equipment such as cleaning scrubber machines and mops, wherever appropriate
- Use high-pressure jet and sprinkler systems, which provide quicker and more efficient cleaning than a regular hose. Consider using water-efficient or green-labelled products.
- Using non-potable sources of water such as recycled water (e.g. rainwater, AHU condensate) for general washing
- Installing flow restrictors in the water supply lines leading to hoses which will help to reduce the flow rate of water used for general washing
- Checking and adjusting nozzle spray patterns for hoses in order to optimise application of sprays
- Ensure facility staff are educated about the importance of water efficient practices

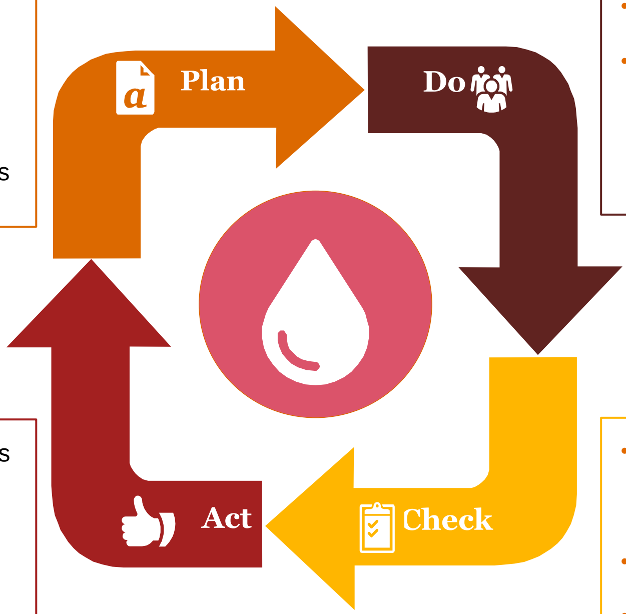
6.3.6. Adopt water efficiency strategy

For industries envisioning sound water use performance, it is essential to adopt systematic approach towards continual improvement through a water efficiency strategy in line with international standards and protocols such as ISO, CSI and others. Such standards use a Plan-Do-Check-Act (PDCA) framework, to enable industries assess and account water use and subsequently help them in identifying goals, targets and implementation plan.

[63] *PUB, Singapore's National Water Agency: Best Practice Guide in Water Efficiency*

- Define policy & objectives
- Define business level KPIs
- Identify regulatory requirements
- Conduct water use review
- Define baseline water use efficiency indicators, targets and action plan

- Implement the water strategy and action plans
- Identify and implement technology and retrofit opportunities in line with the KPI



- Implement continual actions to improve performance against the targets

- Monitor and measure water use patterns against the water policy, objectives and regulations
- Assess the water use against KPIs and targets
- Report the performance

Case of improving water use performance through targets
A leading beverage company adopted a 2020 goal of improving water efficiency in manufacturing operations by 25% (litres of water used per product produced). Such a target has enabled the company to achieve significant reductions in water use ration from 2.7 litres/product to 1.92 litres/product with an improvement of 18% since 2010. Some bottling plants of the company are using 1.7 litres of water, or less, to produce a product.[64]
A global mining company set water usage goals for all its mining sites worldwide, targeting a 20% reduction from projected water consumption by 2020. To meet this target, the company rolled out a 'Water Efficiency Target Tool (WETT) which helps in measuring progress and implementing actions through lessons learned from past years of implementation. The overall strategic intervention has helped the organisation to exceed the 2020 target by achieving 16% reduction against the 2020 projections. Potential water efficiency techniques deployed included dust suppression, dewatering of tailings, efficient ore separation thereby contributing to 25 million m^3 of water savings.[65]
A leading cement company in Asia, set out a specific water consumption target of reducing water withdrawal by 0.5% year on year from the baseline as well as utilizing 100% waste water within the premises without any discharge. These KPIs have enabled the company to achieve over 8% reduction in specific water withdrawal and also pushed the company to hold a 'Zero Liquid Discharge' status by reusing all waste water within the factory premises.[66]

[64] *https://www.coca-colacompany.com/stories/setting-a-new-goal-for-water-efficiency*
[65] *https://www.angloamerican.com/futuresmart/our-world/environment/defining-our-water-future*
[66] *Shree Cement 2016-17 Sustainability Report*

7 Financial management and analysis

7. Financial management and analysis

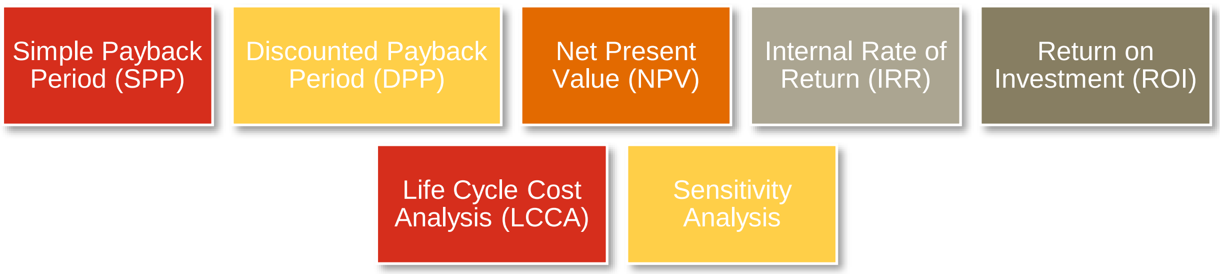
Financial analysis is the process of evaluating projects or investment propositions and identifying the project or investment proposition with the highest potential. The investment would be required for modification, retrofitting and for incorporating new technology. It is imperative to adopt a comprehensive approach to for merit rating of various investment options vis-à-vis the anticipated saving. It is important to identify benefits of the identified measure not only to energy savings but also to other associated benefits like improved product quality, increased productivity and efficiency etc.[67]

Often, within a facility, the multitude & complexity of proposals that come up for consideration by management are from different sections of the facility. As a result, the genesis, objectives, results and needs of the proposals may be quite diverse. In case of investment proposals, the problem further intensifies as the management would like to invest the limited capital to the most attractive proposal which provides highest return on investment. Therefore, it is necessary to establish certain common evaluation criteria which can provide an indication of attractiveness of particular investment proposal as compared to the competing proposals.[68]

There are two common problems faced while considering investments in Energy proposals. The first problem is that organizations generally give preference to investing in their core or profitmaking activities in preference to energy efficiency. The second issue is that even when they do invest in energy efficiency, they tend to expect faster rates of return than they require from other kinds of investment.[67]

In most respects, investment in EE project is no different from any other area of investment. Therefore, when facility management decides to invest in EE project, the same set of evaluation criteria must be applied to the EE investment proposal as would get applied to other investment considerations of the facility.

The following are the most commonly used methods of financial analysis:



7.1. Financial appraisal methods

7.1.1. Simple payback period

Simple payback period is a measure of the amount of time (in years) it takes to recover the initial investment in any project. With reference to resource efficiency, it is the amount of time (in years) taken to recover the initial investment in resource efficiency project considering only the net annual savings from the project. It is one of the simplest investment appraisal techniques.

The simple payback period is usually calculated as follows:

$$Simple\ paybak\ period\ = \frac{First\ cost}{Yearly\ benefits - Yearly\ costs}$$

[67] *Financial Management, Book 1 Chapter 6, Bureau of Energy Efficiency Guide books*
[68] *Training manual for capacity building of banks, Financing Energy Efficiency at MSMEs, Prepared by PwC for SIDBI*

The advantages and limitations of simple payback period (SPP) method of financial appraisal are presented below. A case example is presented in **Box 39**.

Advantages	Limitations
It is simple, both in concept and application. Obviously a shorter payback generally indicates a more attractive investment. It does not use tedious calculations.	It fails to consider the time value of money. Cash inflows, in the payback calculation, are simply added without suitable discounting or compounding.
It favours projects, which generate substantial cash inflows in earlier years.	It ignores cash flows beyond the payback period. This leads to discrimination against projects that generate substantial cash inflows in later years.

Box 39: Simple Payback Period Case Example

Problem: A copper smelting industry uses a smelting furnace. The furnace operates at mains frequency furnace and is an outdated design. Based on assessment of the furnace, the specific energy consumption of the furnace which is high considering process type and operation.

Solution: A high frequency induction furnace technology is proposed to replace the existing furnace. The specific energy consumption of the new furnace is expected to be 850 kWh per tonne as compared to 1362 per tonne for the conventional smelting furnace.

SPP calculation: The purchase and installation cost of new furnace is US $ 130,500, it is expected to save electricity equivalent to monetary saving of US $ 70,500 per year. The maintenance cost of the induction furnace is US $ 5000.

$$Simple\ paybak\ period\ = \frac{130{,}500}{70{,}500-5{,}000} = 2.0\ years$$

7.1.2. Discounted payback period

Discounted Payback period (DPP) is a measure of the amount of time (in years) it takes to recover the initial investment in any project taking into account the time value of money. The different between DPP and SPP is that DPP takes into account the time value of money while discounting the cash flows which is not the case in SPP. The discounted payback period is usually calculated as follows:

$$Discounted\ payback\ period\ = \frac{Actual\ cash\ inflow}{(1+r)^t}$$

Where: r - discount rate and t - period of cash flow

Hence, lower the DPP of the project, the faster the recovery of initial investment and thus better the project. The general rule is to accept projects which have a payback period less than the targeted period. The advantages and limitations of DPP method of financial appraisal are presented below. Case example is shown in **Box 40**.

Advantages	Limitations
It is simple, both in concept and application. Unlike SPP, it takes into account the time value of money while considering the cash flows.	It ignores cash flows beyond the payback period. This leads to discrimination against projects that generate substantial cash inflows in later years.

Box 40: Discounted Payback Period Case Example

Problem: A fertilizer industry had a number of toilets across the factory. Each was installed with standard flush of 13 - 16 litres per flush.

Solution: The low flush cisterns use as little as three liters of water for a short flush and six liters for a long flush, compared to regular cisterns that use 13 liters per flush. A significant amount of water can be saved by replacing all the conventional flushes with low flow flush systems.

DPP calculation: Let us consider a project of replacing regular toilet flushes with low flush cisterns which has the following cash flow stream. Initial cost of project is US $ 750. Savings in 1st, 2nd and 3rd years are US $ 600, 450 and 250. Assumption: Useful life is 3 years, Discount rate is 10%

Year	Cash flow (US $)	Present value (US $)	Cumulative (US $)
1	+600	545	545
2	+450	372	917
3	+250	187	1104

$$Simple\ paybak\ period\ = \frac{750}{600} = 1.25\ years$$

The investment is US $ 750, which falls in between 1st and 2nd year. (Somewhere 1year 7 months)

$$Discounted\ paybak\ period\ = 1.55\ years$$

7.1.3. Return on Investment

Return on Investment (ROI) is an indicator of the “annual return” from the project as a percentage of the capital cost involved in the project. The annual return takes into account the cash flows over the project life and the discount rate by converting the total present value of ongoing cash flows to an equivalent annual amount over the life of the project, which can then be compared to the capital cost.

ROI can be calculated using:

$$ROI = \frac{Annual\ net\ cash\ flow}{Capital\ cost} \times 100$$

This value should always be higher than the opportunity cost that is the cost of money (interest rate) in this case. The higher the value of ROI, better the investment. This metric can be used for evaluating investment opportunity with different time periods and capital costs. It helps in judging whether to go ahead with the investment opportunity or not.

The advantages and limitations of ROI method of financial appraisal are presented below. A case example is presented in **Box 41**.

Advantages

It is simple, both in concept and application.

Return expressed as percentage makes it easier to evaluate against borrowing interest. In general, if RoI is higher than the borrowing interest then it is a profitable investment.

Limitations

It doesn’t consider the time value of money.

It also does not take into account variable annual cash flows which is often the more encountered case in real life analysis.

Box 41: Return on Investment Case Example

Problem: A beverage industry uses high quantity of water in ablution and cleaning process.

Solution: Use of high pressure nozzles reduces quantity of water usage by increasing pressure. These nozzles can be retrofitted on existing cleaning water pipes.

ROI calculation: The industry adopted the high pressure low floe nozzles at an investment of US $ 300 which led to annual monetary saving of US $ 75.

$$ROI = \frac{75}{300} \times 100 = 25\%$$

7.1.4. NPV and IRR

Net Present Value (NPV) gives the aggregate present value of all the cash flows associated with the project or investment opportunity. The NPV is calculated using the following formula:

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{((1+r)^t)}$$

Where: r - discount rate, n - life of project, t - period (0, 1, …, n), CF_t - cash flow occurring at end of period 't'

In general, higher the value of NPV, better the project. The investment proposition or project should be accepted if the NPV is positive and reject it if the NPV is negative. A negative NPV indicates that the project is not achieving the return standard and thus will cause a financial loss if implemented. It can be used for deciding between two different projects. The project with a higher NPV will be preferred over the project with lower NPV.

Internal Rate of Return (IRR) is the discount rate at which NPV of the project is zero. This method helps in calculating the rate of return that the investment is expected to yield. It is derived by the following equation:

$$0 = \sum_{t=0}^{n} \frac{CF_t}{((1+r)^t)}$$

Where: r - Discount rate at NPV=0 is IRR

The discount rate, r, in above formula is calculated by iterations. If this discount rate is greater than current interest rate, the investment is sound. The proposal with higher IRR is usually the preferred choice for investment. Calculation of IRR can be effectively done using a computer spreadsheet, otherwise it is a long iterative process.

IRR is used for comparing different investment alternatives. The project with a higher IRR has a higher rate of return and is thus a better alternative as compared to other projects.

The advantages and limitations of IRR method of financial appraisal are presented below. A case example is presented in **Box 42**.

Advantages	Limitations
It considers the time value of money while discounting cash flows. Unlike SPP and DPP, it considers all the cash flows of the project.	It does not distinguish between borrowing and lending. Therefore, a higher IRR may not necessarily be a better proposition.

Box 42: IRR Case Example

Problem: A fertilizer industry does not have rainwater harvesting system in place. Rainwater harvesting is the accumulation and storage of rainwater for reuse on-site, instead of allowing it to run off which happens most of the times. This leads to wastage of a large amount of reusable water.

Solution: Rainwater from the roofs can is directed in to deep pits and reused with minimal filtration. The harvested rainwater can be used for gardening as well as in the toilets, with proper treatment it can be used for domestic purposes. Moreover, rainwater is simplest method of recharging groundwater.

NPV & IRR calculation: Initial cost of project is US $ 1000. Annual savings is US $ 300. Useful life 10 years. Calculate NPV at discount rate of 15%. Also calculate IRR for the proposal.

Year	Cash flow (US $)	Present value (US $)	Cumulative (US $)
0	-1000	-1000	-1000
1	+300	+260	-740
2	+300	+227	-513
3	+300	+197	-315
4	+300	+171	-143
5	+300	+149	+6
6	+300	+130	+136
7	+300	+112	+248
8	+300	+98	+346
9	+300	+85	+431
10	+300	+74	+505

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{((1+r)^t)} = 505$$

NPV is positive hence the project is recommended for implementation.

$$0 = \sum_{t=0}^{n} \frac{CF_t}{((1+r)^t)}$$

NPV @ 28% discount rate is -19.3 and NPV @ 27% discount rate is +9.3

IRR of the proposal is 27.3%.

7.1.5. Life Cycle Cost Analysis

The Life cycle cost (LCC) of any equipment is the total “lifetime” cost to purchase, install, operate, maintain and dispose of that equipment. LCC analysis can be performed easily using spreadsheet if we have access to all the cost values. The costs are either deterministic (such as acquisition costs, disposal costs etc.) or probabilistic (such as cost of failure repairs etc.).

LCCA is used for comparing and evaluating the costs involved in different equipment. It helps us in deciding which equipment to choose. Most of the organizations are unaware that the initial cost comprises a small portion of the cost while major cost comes from the energy consumption.

Life cycle cost is given by the following equation:

$$LCC = C_{ic} + C_{in} + C_e + C_o + C_m + C_s + C_{env} + C_d$$

Where: LCC - life cycle cost, C_{ic} - initial costs and purchase price,
C_{in} - installation and commission cost, C_e - energy costs,
C_o - operation costs, C_m - maintenance and repair costs
C_s - down time costs, C_d - decommissioning/disposal costs

For financial appraisal of project/proposal these costs can be simplified and three costs can be considered and they are: (1) Investment cost (including commissioning), (2) Energy cost and (3) Service & maintenance cost. A typical case example of LCCA is presented in **Box 43**[69].

Box 43: Life Cycle Cost Analysis Case Example

Problem: The system is a single pump circuit that transports a process fluid containing some solids from a storage tank to a pressurized tank. The plant engineer is experiencing problems with a fluid control valve (FCV) that fails due to erosion caused by cavitation.

Solution: (a) Repair the control valve, (b) Change control valve (c) Impeller trimming and (d) Install VFD & remove control valve

LCCA calculation: The comparison of three potential solutions is done based on LCCA as shown below:

Particular	Repair control valve	Change control valve	Impeller trimming	VFD and remove control valve
Investment cost (US $)	0	5000	2250	21500
Energy cost (US $/year)	11088	11088	6720	5568
O&M cost (US $/year)	4500	500	500	1000
Repair cost US $/ 2 years)	2500	2500	2500	2500
Life time (years)	8	8	8	8
Present value LCC (US $)	113980	91827	59481	74313

Option C i.e. impeller trimming has the lowest life cycle cost, hence is the preferred solution for the problem.

The energy efficient equipment are typically more expensive to purchase initially as compared to standard equipment, but if viewed over the entire life span, the standard equipment are much more expensive because of high energy costs. Hence energy efficient equipment should be chosen based on LCCA not just initial cost.

7.1.6. Sensitivity analysis

The cash flows of the proposals are often based on assumptions that have a certain degree of uncertainty. The present day cash flows, such as capital cost, energy cost savings, maintenance costs, etc. can usually be estimated fairly accurately. Even though these costs can be predicted with some certainty, it should always be remembered that they are only estimates. Cash flows in future years normally contain inflation components which are often "guess-timates" at best. The project life itself is an estimate that can vary significantly.[67]

Sensitivity analysis is an assessment of risk. Because of the uncertainty in assigning values to the analysis, it is recommended that a sensitivity analysis be carried out - particularly on projects where the feasibility is marginal. How sensitive is the project's feasibility to changes in the input parameters? What if one or more of the factors in the analysis is not as favorable as predicted? How much would it have to vary before the project becomes unviable? What is the probability of this happening? [67]

[69] *Pump Life Cycle Cost - A Guide of LCC Analysis, US Department of Energy, https://www.energy.gov/sites/prod/files/2014/05/f16/pumplcc_1001.pdf*

Suppose, for example, that a feasible project is based on an energy cost saving that escalates at 10% per year, but a sensitivity analysis shows the break-even is at 9% (i.e. the project becomes unviable if the inflation of energy cost falls below 9%). There is a high degree of risk associated with this project - much greater than if the break-even value was at 2%[67].

Sensitivity analysis is undertaken to identify those parameters that are both uncertain and for which the project decision, taken through the NPV or IRR, is sensitive. Sensitivity and risk analysis should lead to improved project design, with actions mitigating against major sources of uncertainty being outlined. The various micro and macro factors that are considered for the sensitivity analysis are listed below.

Micro factors	Macro factors
• These are industry level variables that affect the operation of the industry in which the firm operates. • Some examples of micro factors which affect the analysis are as follows: • Capital structure • Operating expense • Changing of forms of finance • Changing the project duration	• These are economic variables that affect the operation of the industry in which the firm operates. • Some examples of macro factors are as follows: • Technology change • Change in interest rate • Change in energy price • Extension of various government subsidized projects

The advantages and limitations of sensitivity analysis as financial appraisal tool are as follows:

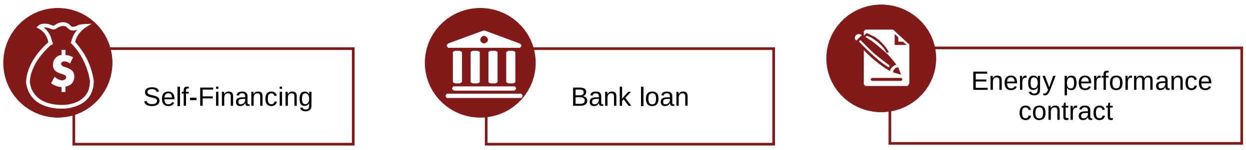
+ Advantages	Limitations −
In-depth analysis: Each independent and dependent variable is studied in detail. Strengthen weak spots: It helps in identifying variables that may act as weakness to the project. Decision making: Since all the variables are considered and outcomes are analyzed in detail, it is an extremely useful tool for future planning. Quality checks: It gives an idea of the variables which have a drastic or a substantial effect on success or failure of a project. Proper allocation of resources: It helps the organization in directing resources to variables that most require these resources.	It does not take into consideration the interrelationship between underlying independent variables. This method considers each variable individually and tries to determine the outcome. In reality, all variables are related to each other. It is based on historical data and assumptions made by the management. There are possibilities that these assumption might itself be wrong. If the assumption are wrong then the whole analysis is wrong.

The sensitivity analysis will bring changes in various items in the analysis of financial statements or the projects, which in turn might lead to different conclusions regarding the implementation of projects.

7.2. Financing options

Financing may be found from any of a variety of sources, including internal funds of industry and loans from financial institutions. For sustainable and sizable channels of financing, however, the local banking sector is ultimately the key in almost every country. Where the local banking sector is too weak, immature, or simply uninterested, any of a variety of arrangements may be worthwhile to provide initial resource efficiency project financing or begin to introduce the resource efficiency lending business into the market. These may involve other public institutions in a variety of ways. Ultimately, however, effective long term solutions are bound to require large-scale, well-constructed involvement of the local banking system[70].

There are a number of financing options for resource efficiency projects but the prominent ones are:



7.2.1. Self-financing

The industry can finance the energy and water saving proposals which have quick payback and or higher ROI. Self-financing has the following benefits:

- Assigning a proportion of energy savings to your energy management budget means you have a direct financial incentive to identify and quantify savings arising from your own activities.
- Separately identified returns will help the constituent parts of your organization understanding whether they are each getting good value for money through their support for energy management.
- If operated successfully, splitting the savings will improve motivation and commitment to energy management throughout the organization since staff at all levels will see a financial return for their effort or support.
- But the main benefit is on the independence and longevity of the energy management function.

7.2.2. Bank loan

The industry can sought loan from a bank either nationalized or corporative or international. The form of capital is a term loan where is bank usually demands a collateral for mitigating risk of non-repayment of loan. The interest rate is variable which depends on repayment ability, size of loan amount & period of loan. The period of loan would depend on size of loan availed and repayment ability.

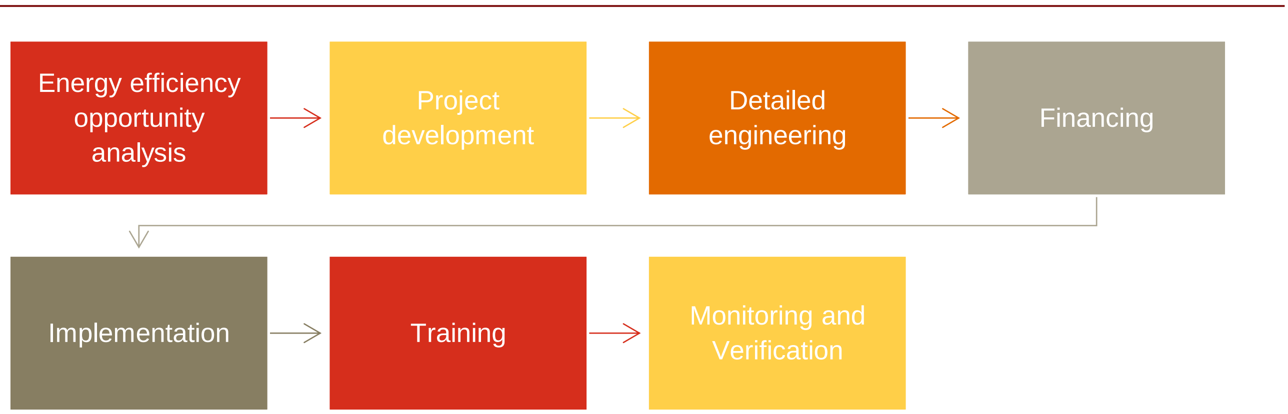
7.2.3. Energy Performance Contracting

If the project is to be financed externally, one of the attractive options for many organizations is the use of energy performance contracts delivered by energy service companies. Energy Services Company (ESCO) is a company who develops and implement Energy Efficiency (EE) projects to save energy and reduce energy costs for their customers. ESCO usually provides the following services:

- Design, Develop, Finance Energy Efficiency projects
- Install, operate and maintain the energy efficient equipment
- Measure, monitor, and verify the project's energy savings
- Assume the performance and financial risk

Energy performance contracting is basically an agreement with an ESCO which involves a plethora of services including:

[70] *Financing Energy Efficiency: Lessons from Brazil, China, India and beyond/ by Robert P Taylor, et. al. ESMAP*



Performance contracting with an ESCO transfers the management and technology risks from the end-user to the ESCO.

Vendor ESCOs	• They are equipment manufacturers and generally don't operate in the utility driven DSM industry & tend to focus on large industrial clients
Contractor ESCOs	• They typically work with contractors in green field construction projects by installing more EE equipment than might have been provided otherwise)
Utility ESCOs	• They bid to serve as providers for utility funded demand side management (DSM) programs and are paid based on electricity savings
Engineering ESCOs	• They perform design and other services but are seldom involved in performance contracts

There are five models for ESCO performance contracting, their features and model is presented below.

7.2.3.1. Shared Saving model

The features of the shared saving model are as follows:

a) ESCO finances the total upfront capital cost of the project.
b) ESCO receives major share of the achieved savings from the project.
c) Facility owner does not have any obligation to pay the loan.
d) ESCO assumes the performance and credit risk.

The model of shared saving ESCO is presented in **Figure 20.**

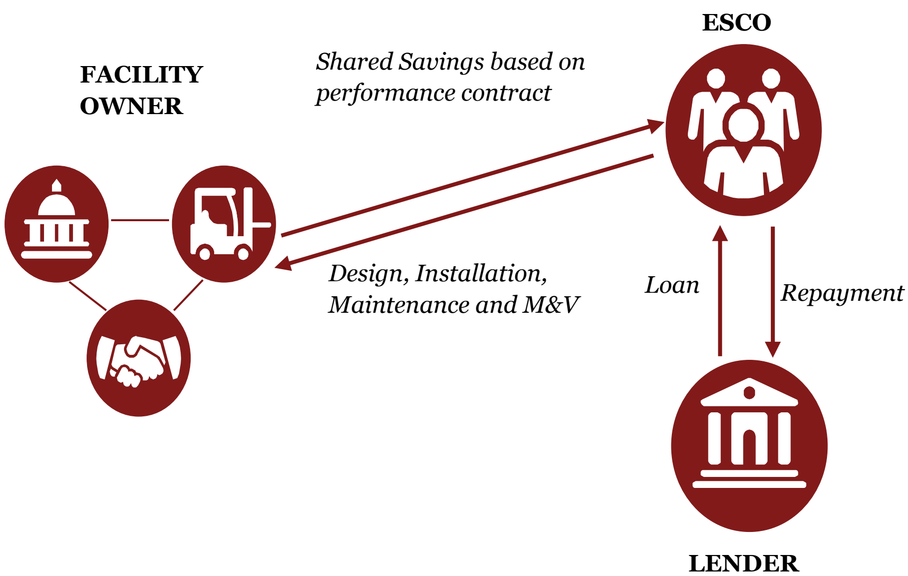


Figure 20 Shared saving model

7.2.3.2. Guaranteed Savings Model

The features of guaranteed savings model are as follows:

a) Facility owner takes loan from financial institution and finances the project
b) ESCO bears no obligation for repayment of loan
c) ESCO guarantees energy savings performance to facility owner
d) Any shortfall in the energy savings from the guaranteed is compensated by the ESCO
e) Savings exceeding the guaranteed level are shared with the ESCO

The model of guaranteed saving ESCO is presented in **Figure 21**.

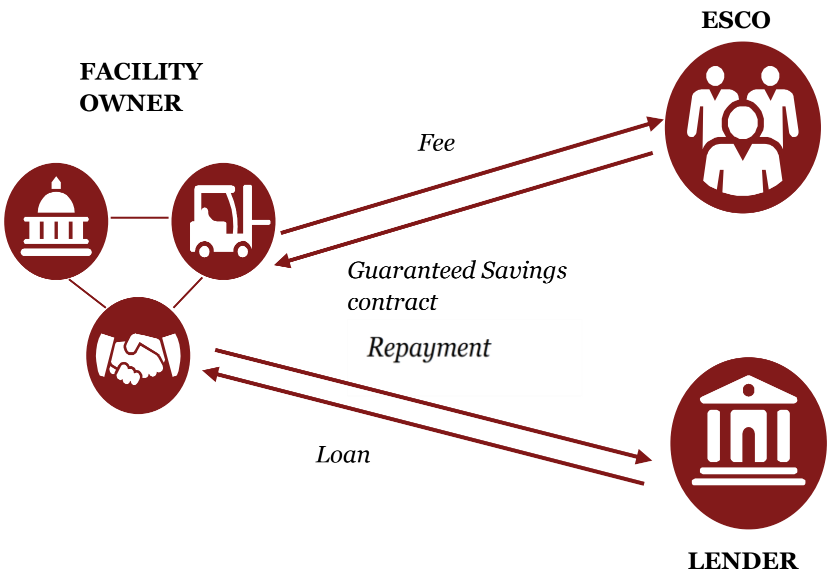


Figure 21 Guaranteed saving model

7.2.3.3. Lease rental method

The supplier installs the equipment and may maintain it. The lease payments are financed by verified savings and the ownership is generally transferred at the end of a lease period. The client (lessee) makes payment of principal and interest; the frequency of payments depends on the contract. The stream of income from the cost savings covers the lease payment.

7.2.3.4. Build-own-operate-transfer (BOOT) model

The model may involve an ESCO designing, building, financing, owning and operating the equipment for a defined period of time and then the transferring this ownership over to the client. This model resembles a special purpose enterprise created for a particular project. Clients enter into long term supply with the BOOT operator and are charged according to the service delivered. The service charge includes capital and operating cost recovery and project profit.

7.2.3.5. Build-own-operate (BOO) model

A new public private partnership (PPP) project model for ESCO business named BOO (Build-own-operate) has been emerging in which a private organization builds, owns and operates the energy efficiency of a facility. The government doesn't provide direct funding in this, but it may offer financial incentives like tax-exempt status.

A comparison of various ESCO models is provided in **Table 40**.

Table 40 Comparison of ESCO models

Contract type	Whose balance sheet	Who takes performance risk	Project specific financing
Guarantee savings	Industry	ESCO	Yes
Shared savings	ESCO	ESCO	No
Lease rental	Industry	ESCO	Yes
BOOT model	ESCO	ESCO	Yes

7.2.4. Other financing options

A comprehensive description of various other financing options for resource efficiency are presented in **Table 41**. The financing instruments mentioned here are either already in use in one form or the other, in various countries, or they are in the conceptualisation phase.

Table 41 Financing instruments for resource efficiency

Instrument	Entity involved			Type of funding	Primary repayment mechanism		Secondary repayment mechanism	Provision for risk mitigation	Geography
	Financier	Service provider	Beneficiary		IF transferable	Mode of repayment			
ESCO	NA	Government	Industry	NA	Yes	NA	NA	Not required	EU (Emission Trading System), India (PAT), France (White Certificates)
On bill financing	FIs	ESCO / DISCOM	Industry, ULBs, MSMEs	Debt (Loan)	Yes	Linked to electricity bill	EMI	Credit worthiness of customers linked to historical electricity bill payments	India (UJALA), USA (New York On Bill Recovery Loan Program, Electric Cooperative of South Carolina - Rural Energy Saving Program)
Capital subsidy	Govern-ment	ESCO/Self	Any (except large industries)	Grant (Government grant/subsidy)	No	Not required to be repaid	N/A	No	India (FAME), USA (EE and Block grant program)
Tax based	N/A	Government	All	N/A	No	N/A	N/A	No	Belgium (Tax deduction for energy saving instruments), USA(New energy efficient home credit)
ESI	Insurance fund pool	ESCO/Local FI/ Insurance companies	All	Premium from EE service providers	No	N/A	One time insurance cover payment	Insurance	USA (Energy savings insurance scheme-Columbia)

Instrument	Entity involved			Type of funding	Primary repayment mechanism		Secondary repayment mechanism	Provision for risk mitigation	Geography
	Financier	Service provider	Beneficiary		IF transferable	Mode of repayment			
Revolving loan fund (RLF)	Gover-nment	Any FI	Any sector ,ESCOs/ OEM's	Grant (Government grant)	No	EMI/ Installments	N/A	No	India (Energy efficiency revolving fund)
Accelerated depreciation based incentivization	N/A	Self-beneficiary	Any sector, ESCOs/OEMs	N/A	No	N/A	N/A	No	UK (Enhanced capital cost allowance scheme)
Revenue decoupling (RD) modes for DSM	N/A	Government	DISCOMs	N/A	N/A	N/A	N/A	N/A	USA (introduced under Clean, renewable and efficient energy act ,2008, in Michigan)
ECB's	Govern-ment aided financial institutions	Banks	Any	Debt (Loan)	No	EMI/ installments	N/A	Risk transfer from end user to government	Green bonds by World Bank
Interest rate buys down fund	Govern-ment subsidy	Banks	Any	Grant	No	EMI/Installments	N/A	No	Japan (low interest loans for building equipment installation)
Loan loss recovery/Partial risk Guarantee fund	Govern-ment	ESCO/Self	FI's	Grant (Government)	No	N/A	N/A	Risk transfer from end user to government	India, USA, China, Hungary, Czech Republic, Slovakia, Latvia, Estonia, Lithuania, Russia, Brazil, Poland, Bulgaria, Sri Lanka
VCFEE	Venture capital firms	VCFEE Fund manager	Any	Equity (Venture funding)	No	Dividend/Capital appreciation/ RoE	N/A	No	India

Instrument	Entity involved			Type of funding	Primary repayment mechanism		Secondary repayment mechanism	Provision for risk mitigation	Geography
	Financier	Service provider	Beneficiary		IF transfe rable	Mode of repayment			
PACE	FIs, institutio nal investors, Govern-ment	Municipaliti es & ESCOs/OE Ms	Property owners	Debt (Loans)	No	Linked to property tax	EMI/Installme nts	Credit worthiness of customers	USA (Efficiency Maine Property Assessed Clean Energy Financing)
CRAFT	Any	FI (Equity fund managers)	EE technology companies, ESCOs	Equity (Equity shares, international financing)	No	Equity capital appreciation	Any	Portfolio diversificati on	N/A
Green Receivables fund	1st Stage-FI, 2nd Stage-Capital Market	FI	Any sector, ESCOs /OEMs	Debt (loan)	No	EMI's/install ments	Coupon/Capit al appreciation	Portfolio diversificati on	Under concept stage
WHEEL	1st stage-FI, 2nd stage-Capital Market	FI	Low and medium income groups	Debt (loans)	No	EMI's/install ments	Coupon/Capit al appreciation	Portfolio diversificati on	Under concept stage
Loans4SM E	Retail/in dividual investors	Online peer to peer lending platform	SMEs	Debt (peer to peer lending)	No	EMI's/install ments	N/A	Credit risk assessment provided by platform	Under concept stage
CEIA	Private investors and govern-ment	N/A	EE projects in ASEAN countries stranded due to capital unavailabili ty	Equity & Debt (Government Grants & private investment equity)	No	EMI's/install ments	N/A	Loss guarantee for PE investors	Under concept stage

Instrument	Entity involved			Type of funding	Primary repayment mechanism		Secondary repayment mechanism	Provision for risk mitigation	Geography
	Financier	Service provider	Beneficiary		IF transferable	Mode of repayment			
Forfaiting funds	FI	N/A	ESCOs/OEMs	Loan amortization	N/A	N/A	EMI/installments	Performance guarantee	Latvian Building energy efficiency fund
Factoring fund	FI	N/A	ESCO's/OEMs	Loan amortization	N/A	N/A	EMI/installments	No	N/A
Operation lease/ Vendor financing	FI	ESCO's/OEMs	Any	Debt (leasing)	No	Lease payment	N/A	Asset as collateral	India (EV Program, EESL), LED Street Lighting Program, EESL
Capital/Financial lease	FI	FI	Any	Debt (leasing)	No	Lease payment	N/A	Asset as collateral	N/A
EIM	FI	N/A	Home buyers	Debt (loans)	No	EMI/installments	N/A	Coupling of mortgage home loan with loan for EE	USA - Energy-Rated Homes of Vermont (ERH-VT) programme, France (eco-mortgages)
Energy efficient mortgage	FI	N/A	New home buyers	Debt (loans)	No	EMI/installments	N/A	Coupling of mortgage home loan with loan for EE	USA
Carbon finance	Carbon fund	FI	Any	Annual monetary support	No	N/A	N/A	No direct risk support	EU (EIB-kfW Carbon programme)
Subordinate debt	FI, Insurance companies, Subordinated debt funds	FI, Insurance companies, Subordinate debt funds	Industries	Debt (Mezzanine Debt)	No	EMI/installment	N/A	No	Europe (The green logistics program EBRD)

Email: ctcn@unep.org
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