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Methodology

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

January 2019

Draft

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1. Unit selection criteria

1.1. Introduction

The technical assistance includes conducting energy and water efficiency audits in ten pilot companies. Ten (10) focus sectors have been identified on a preliminary basis for the assignment by the key ministries in Zimbabwe. The sectors includes: food processing & beverages, leather & footwear, agrochemical, timber processing, mining mineral & metal finishing, cement, cable manufacturing, buildings & construction, waste management and dairy sector. Out of the focus sectors, 10 industrial units have to be selected for carrying out energy and water efficiency audits.

Units from the focus sectors would be rated and ranked on the *Preliminary Rating Criteria* (detailed in later section). The top 3 units from a sector based on the Preliminary Rating Criteria would be then rated on the *Desirable Criteria*. The unit with the highest score after applying the desirable criteria would be finalized for a sector. The indicative engagement pipeline for industrial units is provided in **Figure 1**.

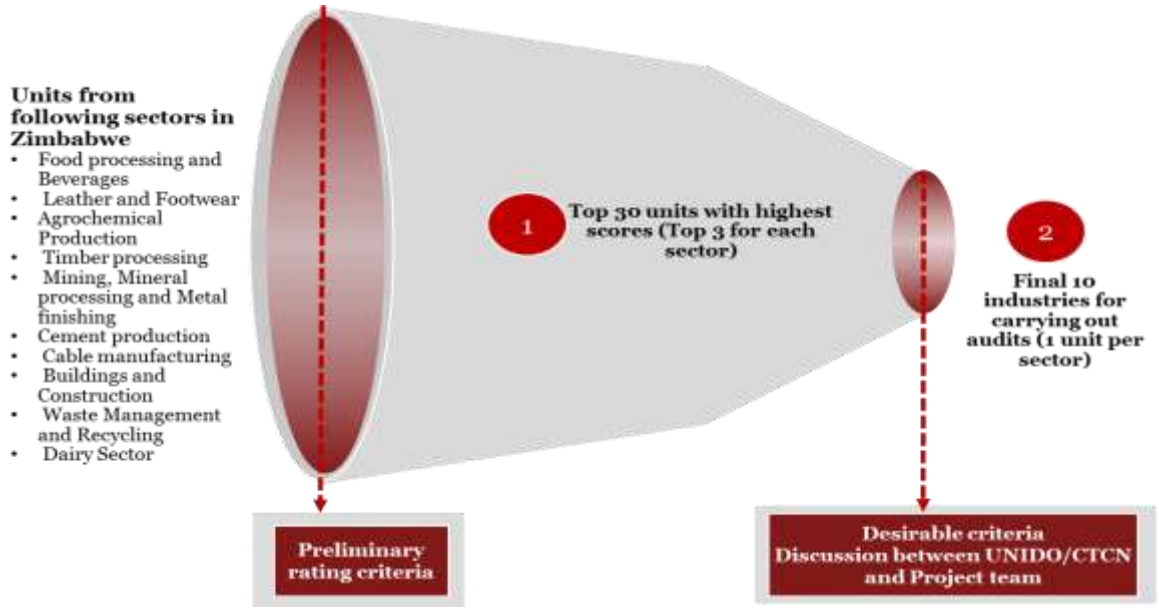


Figure 1: Indicative engagement pipeline

1.2. Assumptions

1. The methodology has been prepared considering data of approximately 10 units to be available for each sector under consideration. If the number of industries for which data is available is much less, then instead of using median values an appropriate value would be defined through discussions between project team and UNIDO/CTCN.
2. If the number of units to start with in a sector is less than or equal to 3, then the Desirable criteria would be directly applicable.

1.3. Preliminary rating criteria

Units would be segregated into SME and Large industries based on their membership of SME association or qualification to become member. The definition of small (turnover less than $240 000 or assets less than $100 000) and medium enterprises (turnover and assets above the thresholds for small enterprises, but less than $1 million each). The points obtained for each parameter would be multiplied by the corresponding weightage to obtain the score for each parameter. The parameter scores of all 7 parameters would be added to obtain the final score on preliminary rating criteria.

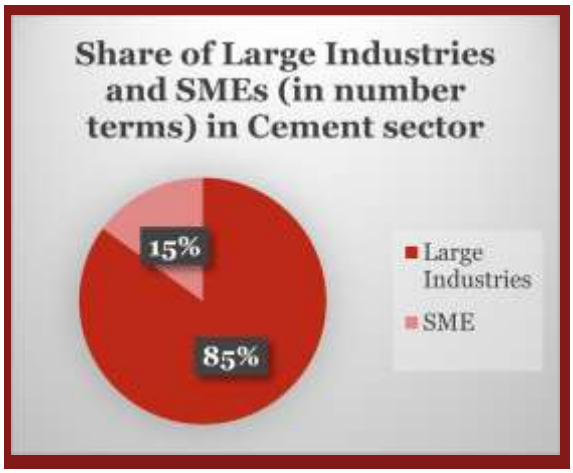
1.3.1. Description of criteria

1. **Category of operating scale of a unit (Pre-dominant/Not pre-dominant):** This criterion has been created to ensure high potential for scalability of the pilot projects within an industrial sector. Greater weightage has been provided in the scoring for a unit which belongs to a predominant[1] category of operating scale (Large/Small and Medium Enterprise) for a specific industrial sector**.**

***For example**:*

Let us consider that scoring is being done for units in Cement sector. In the cement sector, the distribution of large industries and SMEs is as depicted in the figure below. Let us consider a unit named XYZ Ltd. whose scoring is being done. XYZ Ltd. is a Large Industry, so it belongs to a predominant category. The scope of replicating demonstration projects carried out in XYZ Ltd. is high.

Let us consider another unit PQR Ltd. whose scoring is being done. PQR Ltd. is a SME, so it belongs to a 'not predominant' category. Therefore, the scope of replicating demonstration projects carried out in PQR Ltd. is low.



If the share of the predominant category is greater than 90% (in number terms) and the unit being scored doesn't fall under the predominant category, the score on all other criteria (Criteria no 2 to 8) would be evaluated as zero. In the above mentioned example, if the share of large units in the cement sector would have been greater than 90%, the scoring for PQR Ltd. (which is a SME) would automatically be calculated as zero for points 2 to 8.

2. **Capacity utilization of unit:** The rationale for using capacity utilization is that, the higher the capacity utilization, the quicker would be the payback of the investment for energy and water savings.

Capacity utilization is defined as: ***Average number of hours of operation per year over past 3 years/Design hours of operation per year.***

The capacity utilization of all units in a sector would be calculated and grouped into slabs provided in Point 2 of Error! Reference source not found.. Points would be allotted to a unit based on the slab where it is placed.

3. **Energy intensity of unit relative to median energy intensity for the sector:** The greater the energy intensity of a unit, the higher would be potential for savings. *Since emission intensity of production varies directly with energy intensity, this criteria is assumed to be inclusive of the emission consideration as well*. Units belonging to an industrial sector would be arranged in ascending order based on their energy intensity (sum of thermal and electrical energy consumption expressed in Tonnes of Oil Equivalent divided by Production in tonnes). The unit with median energy intensity value would be identified. The energy intensity of all other units in the sector would be calculated relative to the identified median energy intensity and grouped into 4 slabs as provided in Point 3 of **Table 1.** Points would be allotted to a unit based on the slab where it is placed. Indexing the energy intensity of all units w.r.t the median energy consumption would ensure that a representative scale of operation is considered in preliminary screening.

4. **Water use intensity of unit relative to median water use intensity for the sector:** The greater the water use intensity of a unit, the higher would be potential for savings. With this rationale, Units belonging

[1] If for a sector, SME industries constitute a major share i.e. >50% (in number terms), then SME is the predominant category of operating scale.

to an industrial sector would be arranged in ascending order based on their water use intensity (water consumption in litres divided by Production in tonnes). The unit with median water use intensity value would be identified. The water intensity of all other units in the sector would be calculated relative to the identified median water intensity and grouped into 4 slabs as provided in Point 4 of **Table 1**. Points would be allotted to a unit based on the slab where it is placed. Indexing the water intensity of all units w.r.t the median water consumption would ensure that a representative scale of operation is considered in preliminary screening.

5. **Management willingness level:** The objective of using this parameter is to retain only the units whose management is interested already or can be convinced to participate in the audit exercise. Based on a high level assessment carried out by project team (in discussion with BCSDZ and other industrial associations), the industries of a sector would be placed into 3 slabs as provided in Point 5 of **Table 1.**Points would be allotted to a unit based on the slab where it is placed.

6. **Plant Vintage:** The older the industry, the higher is the likelihood of inefficient operations (from water and energy use perspective). Based on the year of establishment, the industries of a sector would be placed into 4 slabs as provided in Point 6 of **Table 1**. Points would be allotted to a unit based on the slab where it is placed.

7. **Status of ISO 50001 certification available with the unit:** With this parameter it is intended to provide a higher weightage to units which have not implemented ISO 50001 (and can significantly benefit from the training proposed as a part of this assignment) or have implemented ISO 50001 using ad-hoc local certification (which lends itself to improper knowledge of standard procedures). Units of a sector would be placed into the slabs as defined in Point 7 of **Table 1**. Points would be allotted to a unit based on the slab where it is placed.

8. **Geography where industry is located:** The objective of using this parameter is to provide a greater preference in selection to the unit which is situated in one of the four key industrial areas of Zimbabwe, namely Harare, Bulawayo, Manicaland and Midlands. Units located in other areas would be given less weightage in selection.

Table 1: Preliminary Rating Criteria

Sl. No	Parameter (1)	Slabs for Scoring (2)	Weightage (3)	Parameter Score (2 x 3)
1.	**Category of operating scale of a unit**	a) Pre-dominant (>50%) - 1 pt. b) Not pre-dominant (<50%)- 0.50 pt.	10%	Calculated using excel sheet
Note: If the industry is a member of SME association of Zimbabwe/qualified to become a member of SME association of Zimbabwe, it is to be scored according to Column 4 (Score for SME), else according to column 3 (Score for Large Industries).				
Sl. No (1)	**Parameter (2)**	**Slabs for scoring for Large Industries (3)**	**Slabs for scoring for SME (4)**	**Weightage (5)**	**Parameter Score** (5 x 4)
2.	**Capacity utilization of unit[2]**	a) >75%- 1.0 pt. b) 50-75%- 0.75 pt. c) 35-50%- 0.50 pt. d) <35%- 0 pt.	a) >60%- 1.0 pt. b) 40-60%- 0.75 pt. c) 20-40%- 0.50 pt. d) <20%- 0 pt.	15%	Calculated using excel sheet
3.	**Energy intensity of unit relative to median energy intensity for the sector**	a) More than 1.5 times median value - 1 pt. b) 1- 1.5 times median value - 0.75 pt. c) .75 to 1 times median value -0.50 pt.	a) More than 1.2 times median value - 1 pt. b) 1- 1.2 times median value - 0.75 pt. c) 0.75 to 1 times median value -0.50 pt.	15%	Calculated using excel sheet

[2] Defined as Average number of hours of operation per year over past 3 years/Design hours of operation of a similar industry

		d) Below 0.75 times median value - 0 pt.	d) Below 0.75 times median value - 0 pt.		
4.	**Water use intensity of unit relative to median annual water use intensity for the sector**	a) More than 1.5 times median value – 1.0 pt. b) 1.0- 1.5 times median value - 0.75 pt. c) 0.75 to 1.0 times median value -0.50 pt. d) Below 0.75 times median value - 0 pt.	a) More than 1.2 times median value – 1.0 pt. b) 1- 1.2 times median value - 0.75 pt. c) 0.75 to 1 times median value -0.50 pt. d) Below 0.75 times median value - 0 pt.	15%	Calculated using excel sheet
5.	***Management willingness level****	a) Interested- 1.0 pt. b) Partially Interested, needs convincing- 0.5 pt. c) Not interested at all- 0 pt.		15%	Calculated using excel sheet
6.	**Plant vintage**	a) Established earlier than 1980- 1.0 pt. b) Established in 1980s to 1990s- 0.75 pt. c) Established in 1990s to 2010- 0.50 pt. d) Established after 2010- 0.25 pt.	a) Established earlier than 1980- 1.0 pt. b) Established in 1980s to 1990s- 0.80 pt. c) Established in 1990s to 2010- 0.60 pt. d) Established after 2010- 0.40 pt.	15%	Calculated using excel sheet
7.	**Status of ISO 50001 certification available with the unit**	a) No certification- 1 pt. b) Yes, ad-hoc certification from Local Body - 0.50 pt. c) Yes, from accredited National Body- 0 pt.		5%	Calculated using excel sheet
8.	**Geography where industry is located**	a) Harare/Bulawayo/Manicaland/Midlands 1pt. b) Any other- 0.5 pt.		10%	Calculated using excel sheet
Final Score for Unit					Calculated using excel sheet

Units scoring '0 pt' on Point 5 (Management willingness) shall not be considered for further stages

1.4. Desirable Criteria

The desired criteria are applied on top 3 units of a sector based on preliminary rating scores, which is shown in **Table 2.**The points obtained for each parameter would be added to the overall score of obtained by the top 3 units. Units not meeting the criteria would be awarded 0 points in this stage. The unit scoring the maximum (ranked as 1 as per the excel sheet) shall be chosen for carrying out audits.

1.4.1. Description of criteria

1. **Membership of any nationally recognized industrial association (preferably BCSDZ):** Membership of a nationally recognized industry association would be useful as it would imply less time for securing management buy-in for participating in this initiative. It is also expected that industries in an association are clustered in few key geographical zones, which may be useful in replication.

2. **Management Willingness to co-invest in the project:** The overall objective of the assignment is to enable investments in Energy and water efficiency to be a self-sustaining process. Therefore, having industry management willingness to co-invest in the project would be a positive aspect to influence industry perception and scaling up of the initiative.

The score of the desirable criteria would be added to the preliminary rating scores to arrive at the final scores. The top units for an industrial sector based on the final scores would be deliberated upon and finalized.

Table 2: Desirable criteria

Sl. No	Parameter	Points
1.	**Membership of any nationally recognized industrial association (preferably BCSDZ)**	0.40 pt
2.	**Management Willingness to co-invest in the project**	0.60 pt

1.5. Data collection format

For the following questions (**Table 3**), Industrial units would be required to choose the applicable options.

Table 3: Data collection format for industrial units

Parameter	***Industry response***
1. Name of unit	
2. Contact Details a. Address of the Unit b. Name of the representative c. Contact number (mobile/ landline number d. Email id	
3. Type of Unit **(Any one option to be chosen)** a. Large Enterprises b. Small & Medium Enterprises (SME)	
4. Unit belongs to which sector **(Any one option to be chosen)** a. Food processing and Beverages b. Leather and Footwear c. Agrochemical Production d. Timber processing e. Cement production f. Mining, Mineral processing and Metal finishing g. Cable manufacturing h. Buildings and Construction i. Waste Management and Recycling j. Dairy Sector	
5. Geography where industry is located **(Any one option to be chosen)** a. Harare/Bulawayo/Manicalands/Midlands b. Others	
6. Is the factory a member of SME association of Zimbabwe/qualified to become a member of SME association of Zimbabwe? **(Any one option to be chosen)** a. Yes b. No	
7. Management willingness level **(Any one option to be chosen)**	

Parameter	***Industry response***
a. Interested b. Partially interested needs convincing c. Not interested	
8. Energy consumption data for Financial year 2017-18 **(Applicable option to be chosen)**	
a. Annual Coal Consumption (tonnes)	
b. Annual Coke Consumption (tonnes)	
c. Annual LPG consumption (tonnes)	
d. Annual Fuel Oil consumption (tonne)	
e. Annual LDO Consumption (kl)	
f. Annual HSD Consumption (kl)	
g. Annual Kerosene Consumption (kl)	
h. Annual Biomass (Solid) Consumption (tonnes)	
i. Annual Biofuel(Biodiesel) Consumption (kl)	
j. Annual Natural gas consumption (SCM)	
k. Annual Electricity Consumption purchased from grid + captive power plant (kWh)	
9. Annual production (tonnes) of Financial Year 2017-18	
10. Annual water consumption (cu.m) of Financial Year 2017-18	
11. (a) Actual annual hours of operation (2015-16)	
(b) Actual annual hours of operation (2016-17)	
(c) Actual annual hours of operation (2017-18)	
12. Design annual hours of operation of industrial unit	
13. Plant Vintage **(Any one option to be chosen)** a. Earlier than 1980 b. 1980 to 1990 c. 1990 to 2010 d. After 2010	
14. Status of ISO certification **(Any one option to be chosen)** *a)* No certification *b)* Ad-hoc from local body ***c)*** From accredited body	
15. Membership of any nationally recognized industrial association (preferably BCSDZ) **(Any one option to be chosen)** a. Yes b. No	
16. Management Willingness to co-invest in the project **(Any one option to be chosen)** a. Yes b. No	

2. Training approach & methodology

2.1. Classroom training

The way in which a training module is delivered by the expert has a big role to play in influencing the level of interest of the audience and their takeaways from the session. One of the most popular and proven adult learning approaches used for a variety of training and capacity building for adult professionals is the 70:20:10 model. PwC proposes to implement a training programme structure based on this unique and adult focused learning system.

Based on the model, the entire training curriculum and learners' time will be divided in the ratio 70:20:10 as illustrated next - 70% focused on experiences, group-activities, problem-solving, concept-application, relevance to core business; 20% focused on developmental relationships and feedback from the trainers on evaluation of group activities/exercises, etc.; and 10% focused on formal training through learning of theoretical concepts.

Some of the methods and their advantages are provided in the table below:

Table 4: Interactive methods of training

Method	Useful for	Advantages
Case study	• Solving problems • Changing Attitudes • Building analytical skills	• Involves learners actively • Allows sharing of leaners' experiences with others • Stimulates ideas and discussions of concrete subject
Role playing	• Developing interactive knowledge and modifying attitudes • Introducing humor and liveliness into training	• Stimulates interest • Keeps participants active • Uses participants' experiences
Group Exercise	• Team building • Developing interactive skills • Studying group dynamics	• Facilitates high participation of motivated learners
Brainstorming	• Stimulating creative thinking • Generating positive solutions • Consolidating past learning • Providing diversion	• Promotes active participation of learners • Uses learners' experiences and ideas
Demonstration	• Showing correct procedures and required standards	• Stimulates lot of interest • Can be used for large groups

To the greatest extent possible, multimedia tools shall be used for enabling greater understanding and participation. Every module shall have a de-briefing session to summarize the learnings from the session.

2.2. Hands-on training

The capacity of the staff of the demonstrations units and interested candidates from the classroom training will be developed further by hands-on training during the field assessment study. The aim is to complement theoretical knowledge with actual on-site experience.

The participants will get to experience first-hand the approach and execution of energy and water audit. Candidates based on their respective educational, professional background and interest would be training on different aspects such as electrical assessment, thermal assessment, water assessment, renewable energy potential assessment and data collation.

3. Energy & Water Audit methodology

3.1. Introduction

The project team will conduct a comprehensive energy and water audit in the 10 selected demonstration companies shortlisted based on the criteria explained in previous section. 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 execution depicting various tasks, activities & outcomes is presented in **Figure 2**.

3.2. Initial preparatory work & inception meeting: Step 1

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 will organize an inception meeting with UNIDO/CTCN team at the onset of the assignment. It will be great if representatives from different industries also participate in the inception meeting. During the inception meeting, the discussions will happen along following points:

- 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

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

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

3.3. Collection and analysis of time series data: Step 2

In the context of proposed assignment, this step will also determine the quantum of readily available information with the industries and the needs/extent of analysis required.

Post the inception meeting, the project team will circulate a data collection questionnaire for water and energy audit to all 10 demonstration plants. The questionnaire is divided in five (5) parts:

a) Basic information about the plant facility like production process
b) Energy profile of the plant set-up: Historical energy (and electrical) data - monthly as well yearly
c) Energy management profile, legal requirements of the plant for ISO 50001
d) Major energy consuming equipment: installed equipment inventory (design), its operating parameters such as operating hours, actual load and any operational restrictions. Maintenance plans and procedures.
e) Renewable energy potential (solar, biomass, etc.)
f) Water consumption data: Historical monthly/yearly for entire plant and in key sub-process/equipment.

The questionnaire has provisions for the industry to provide any other relevant information, if necessary.

The questionnaire is in compliance with ISO 50001. It captures the industries present energy management profile, legal frameworks and compatibility for compliance with ISO 50001 Energy Management System Certification. The questionnaire will identify plant readiness to meet the requirements of ISO 50001.

The project team will analyse this data to establish energy and water consumption baselines of the plants. These baselines will be depicted in form of energy and water performance indicators (EnPIs) and these EnPIs will be compared industry benchmarks. To enable the identification of thrust areas where significant potential for energy/water conservation exists.

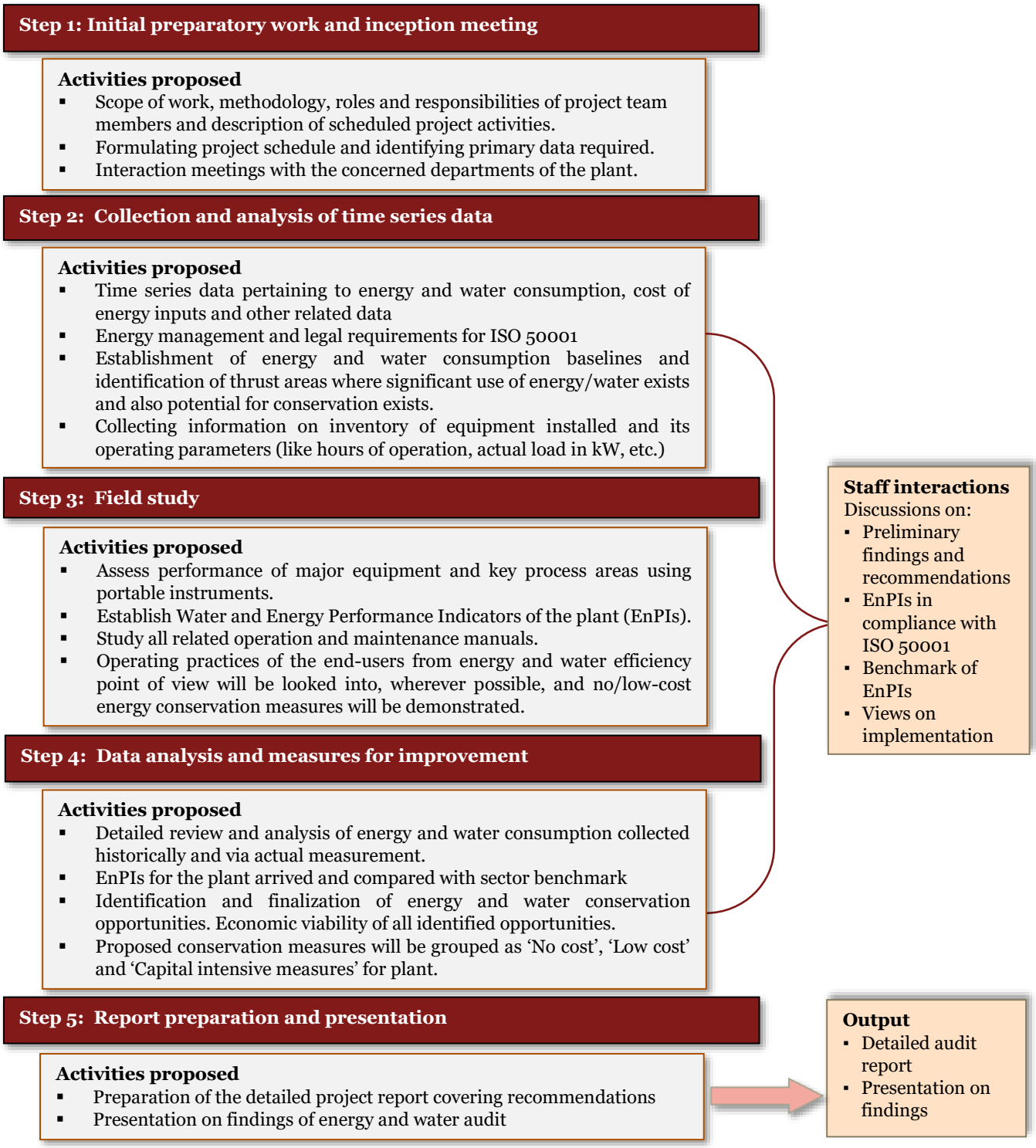


Figure 2: Energy and water audit methodology

The project team will provide guidance to fill the questionnaire, if gaps still exits, they would be plugged during the field visit.

The detailed energy and water audit questionnaire for individual companies in compliance with ISO 50001 Energy Management System Certification is provided at the end of the document.

3.3.1. 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 will define the system boundaries for each of the ten (10) identified companies. The study will be carried out for equipment and process falling within these boundaries (**Figure 3**).

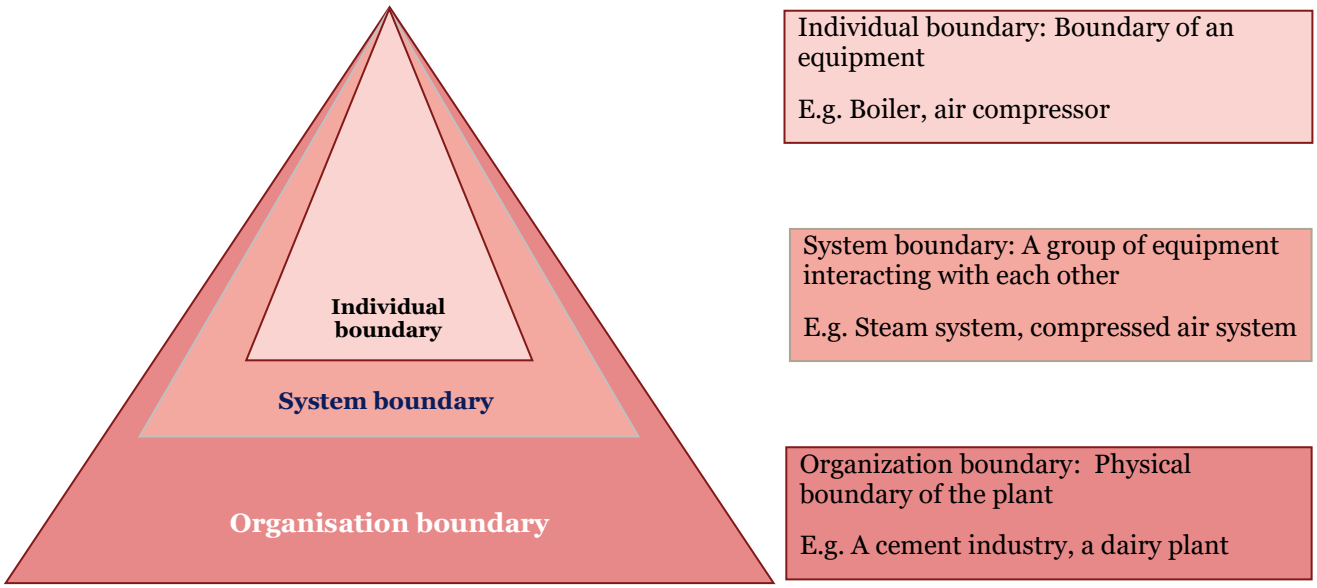


Figure 3: System boundaries

3.4. Field study: Step 3

To conduct comprehensive audit of the shortlisted demonstration companies, the project team proposes to form multiple teams constituting of 2 members, each having experience on the thermal, electrical and water systems. This apart, we will also include industry specific process experts for the field visit, wherever possible and applicable.

Thereafter, a field movement plan for different teams would be developed. This plan shall comprise week-wise schedule of the teams based on:

- Availability of the nodal person of the respective plants
- Plant load condition, operation of plant, etc.

The individual teams will then visit 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.

3.4.1. Initial meeting/personnel interview with company officials

On the first day of the visit to the industry, the project team will organize 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 will interact during the course of field measurements. The project team thereafter will take a walk-through of the industry to know exact locations, energy and water consuming equipment and plan arrangements for the measurements schedule.

3.4.2. Field study and measurements

The project team will scrutinise 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 project team will utilize its own state-of-the art energy/water audit instrument kit for undertaking measurements. A partial list of the audit instruments available with PwC is presented in **Figure 4**.

Figure 4: Energy and water audit instruments

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

Detailed methodology to be adopted for carrying out field measurement and the study of above mentioned equipment is presented below ***(subject to applicability and suitability to the selected companies)***:

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 • Indoor air relative humidity • 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	**Auxiliary 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

3.4.2.2. 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). The 'part E' of structured questionnaire would help identify total roof area available for harnessing solar energy. Based on availability of potential, suitability of technology options such as solar water heater (SWH) and solar roof-top photovoltaic (SPV) will be assessed. The team will make use of open source software tool such as RETScreen, PVsyst, etc. for solar potential assessment.

3.5. Data analysis and measures for improvement: Step 4

At the end of the field measurements, the project 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 5**).

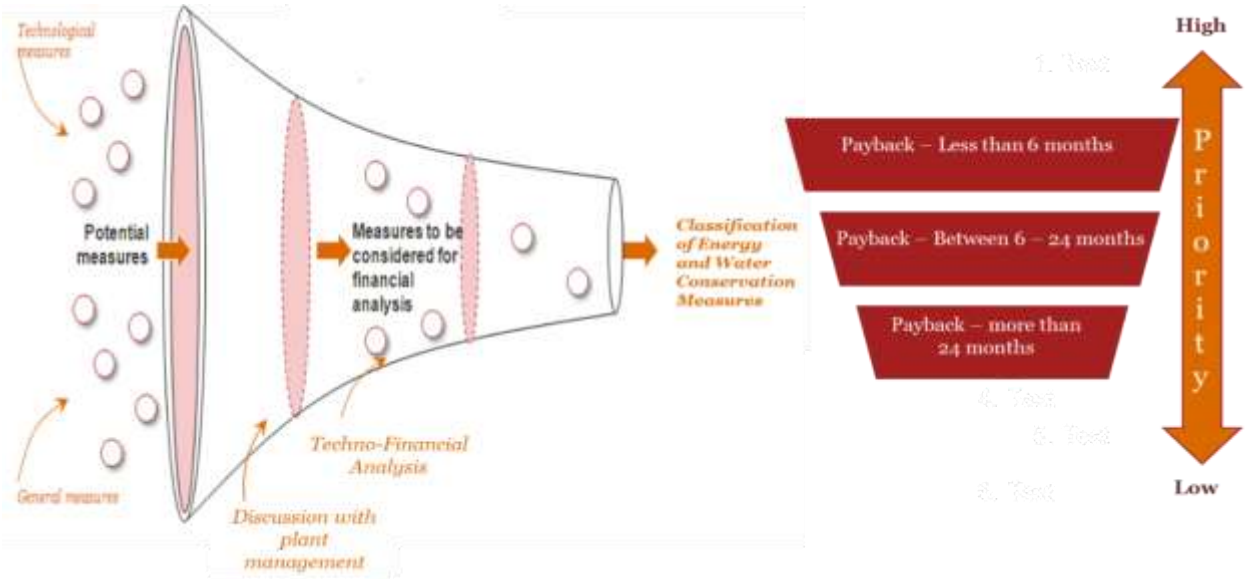


Figure 5: Equipment-wise audit methodology

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 will try to implement the no cost measures to realize the energy savings by the plant immediately.

3.5.1. Tools

The project team will make use of its in-house *Microsoft Excel based tools* (see figure) to assess performance of the equipment and systems. The team will make use of proven tools for identification of EnPIs and performance

assessment such as *material balance* and *energy balance* (**Figure 6**). The project team has vast experience is utilising 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 will identify suitable tools for the assignment. The team will make use of open source software tools such as RETScreen, PVsyst, etc. for renewable energy potential assessment. The team will look for case studies and opportunities for saving energy and water by referring to online tools such as Energy Star.

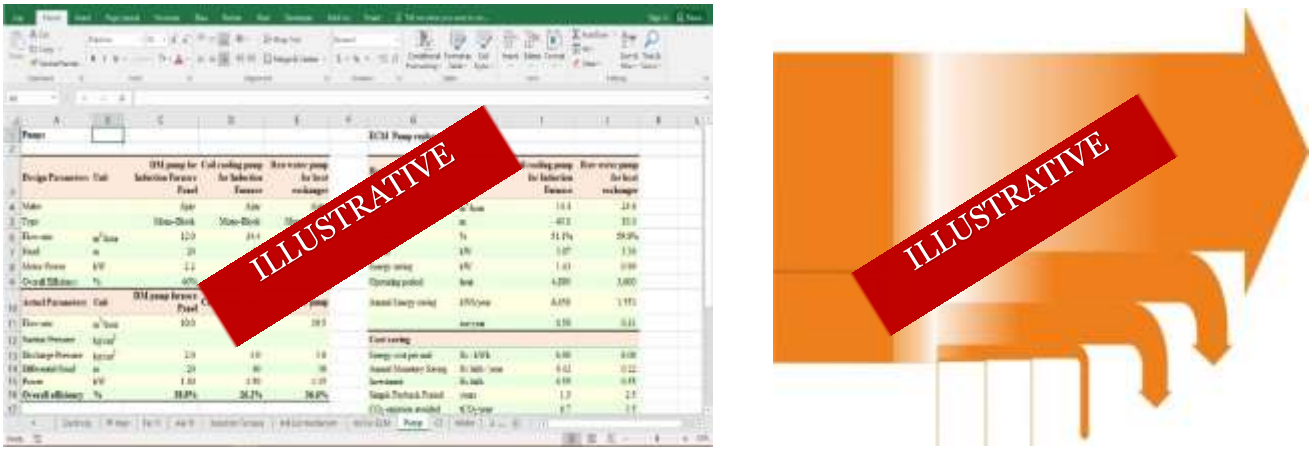


Figure 6: Audit tools illustration

3.6. Report preparation and presentation: Step 5

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 7**:

- 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 keeping in view the energy cost
- Low and no cost energy and water conservation opportunities
- List of instruments and devices used during audit with accuracy level and traceability of calibration status

Figure 7: Table of contents of audit report: Illustrative

The project team would submit the draft audit reports to UNIDO/CTCN/respective companies and will 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.

3.7. Energy and Water Audit questionnaire

The questionnaire for energy and water audit of companies in Zimbabwe comprises of following six sections:

A. General information
B. Energy profile
C. Energy management, legal requirements for ISO 50001
D. Major energy consuming equipment
E. Renewable energy potential
F. Water consumption

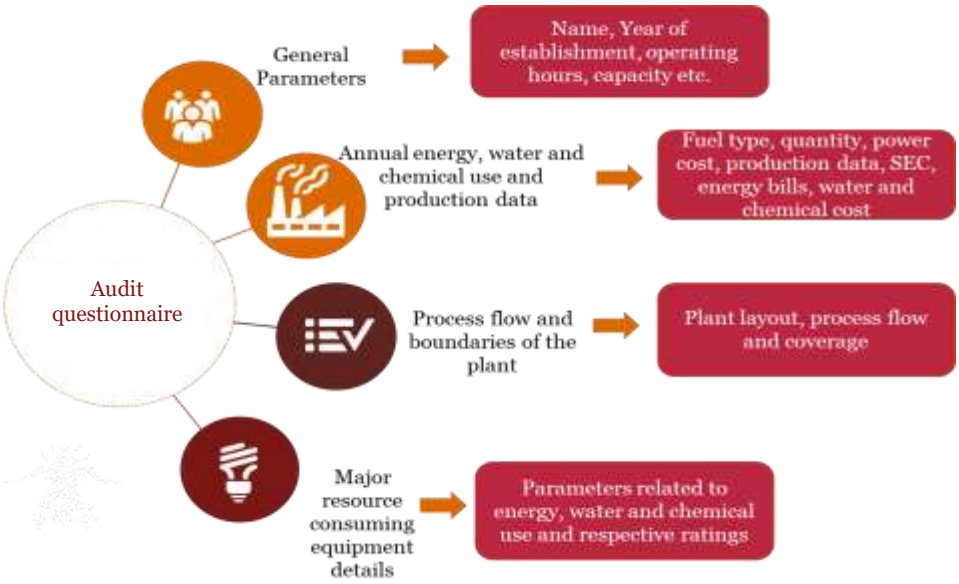


Figure 8: Audit questionnaire pictorial view

3.7.1. General information

This section focuses in basic information such as plant name and location/address, owners, management representative, number of employees, category of industry. This section will also collect information of production process and production levels of the plant.

3.7.2. Energy Profile

The energy profile of an industry is of prime importance in understanding the need and focus area for energy and water audit. This section will collect information on different type and quantities of fuels and electricity consumed by the plant. It will also emphasis on tariff-structure of electricity and cost of other fuels utilised.

3.7.3. Energy management, legal requirements for ISO 50001

The questionnaire is in compliance with ISO 50001. It captures the industries present energy management profile, legal frameworks and compatibility for compliance with ISO 50001 Energy Management System Certification. The questionnaire will identify plant readiness to meet the requirements of ISO 50001.

3.7.4. Major energy consuming equipment

The instruments required for field study measurements depend on the major energy and water consuming equipment in the plant. This section will concentration on various process and auxiliary equipment installed. It will collect design, operational parameters and emphasis on the EnPIs of equipment and systems.

3.7.5. Renewable energy potential

This section will collect information regarding renewable energy such as solar, biomass and other relevant forms. Information about resource assessment, potential, scope of integration will be collected.

3.7.6. Water consumption

The EnPIs for water will be established based on data collected in this section. It will focus on overall plant level water consumption, different types of water used and cost of water.

The detailed energy and water audit questionnaire for individual companies in compliance with ISO 50001 Energy Management System Certification is provided at the end of the document.

Energy and Water Audit Questionnaire

(A) GENERAL

1.	**Name**	
2.	**Postal address**	
3.	**Year of establishment**	
4.	**Web-site (if any)**	
5.	**Name of owner/MD/chairman** **Email ID** **Telephone**	
6.	**Co-ordinating officers:** **Name** **Position** **Email ID** **Telephone**	
7.	**Annual Turnover 2017-18 (US $)**	
8.	**Category of industry** **(Large / Medium / Small)**	
9.	**Type of operation** **(Continuous/Batch)**	
10.	**Working days/year**	
11.	**Number of employees**	
12.	**Certification (Such as ISO 9001, ISO 14001, ISO 50001)**	
13.	**Affiliation to any other local body**	

14. Production process*
Brief description *(Attach process flow diagram)*

15. Production details (FY 2017-18):*		
Product name	**Installed capacity**	**Actual production**

** Attach additional sheet if space not sufficient*

(B) ENERGY PROFILE

1. Annual Energy consumption (FY 2017-18):			
Fuel **	**Unit**	**Quantity**	**Expenditure (BDT)**
Coal	tonne		
LPG	m^3		
Liquid fuel oil	tonne		
Natural gas	m^3		
Electricity			
▪ Purchased	kWh		
▪ Captive	kWh		
Others (Please specify such as biomass, biofuels, solar)			

*** Strike out whichever is not applicable*

2. Electricity tariff (FY 2017-18):		
Tariff category (Low/Medium/High voltage)	kV	
Energy charge	US $/kWh	
Peak time energy charge	US $/kWh	
Off-peak time energy charge	US $/kWh	
Demand charge	US $/kVA	
Power Factor rebate or penalty	US $/kWh	

3. Electricity:		
Total plant connected load (kW)	kW	
Contract demand (kVA)	kVA	
Maximum demand registered	kVA	
Average power factor	pf	

** Please attach last twelve months electricity bill copy*

4. Fuel price (FY 2017-18):		
Coal	US $/tonne	
LPG	US $/$m^3$	
Liquid fuel oil	US $/tonne	
Natural gas	US $/$m^3$	
Others (Please specify such as biomass, biofuels)	US $/unit of fuel	

(C) ENERGY MANAGEMENT, LEGAL REQUIREMENTS FOR ISO 50001

S. No.	Particular	Yes/No	Remarks
Commitment and policy			
1.	Does the organisation have an 'Energy Policy' in place?		
2.	Is the 'Energy Policy' communicated to all employees?		
3.	Do the organisation have a 'Management representative' for energy aspects?		
Planning			
4.	Does the organisation register opportunity for improving energy efficiency		
5.	Does the organisation have energy profile of the plant		
6.	Does the organisation recognise Key Performance Indicators (KPIs) of the plant?		
Implementation and operation			
7.	Is the plant competent and qualified in energy and energy efficiency improvements?		
8.	Are roles and responsibilities for improving energy performance defined?		
9.	Have there been awareness training on energy management?		
10.	Have you engaged the services of a consultant for energy audit?		
11.	Have you engaged the services of a consultant for water use audit?		
12.	Has the organisation established energy saving targets?		
Checking			
13.	Does the organisation have sub-metering of electricity in the plant?		
14.	Does the plant measure, record and monitor major energy consumption sections/equipment?		
15.	Does the organisation compare the KPIs against similar industry in Zimbabwe and abroad?		
Review of energy management system			
16.	Does the plant have an energy management system in place?		
17.	Are the energy records reviewed by the management?		
18.	Would you consider implementing ISO 50001 energy management standards at your plant?		

(D) MAJOR ENERGY CONSUMING EQUIPMENT DETAILS

Facility	√ / X	No. of units
Boiler		
Thermic fluid heater		
Furnace		
Kiln		
Chiller		
Air compressor		
Pump		
Cooling tower		
Fans/blowers		
Electric motor		
Transformer		
Diesel generator set		
Lighting		

Process equipment (please specify)	No. of units

1. Boilers & Hot water generator

Boiler ID	Type	Serving area	Design Data - Steam		Fuel consumption (T/hr)	Performance indicator	
			Generation (T/hr)	Pressure (kg/cm²)		Boiler efficiency	Evaporation ratio

Total no. of steam traps installed :

Type of steam traps:

2. Thermic Fluid Heaters

Heater ID	Type	Serving area	Rated capacity (Mkcal/hr.)	Fuel consumption (T/hr)	Performance indicator (T fuel/Mkcal)

3. Furnaces/kilns

Furnace/ kiln ID	Type	Serving area	Design capacity	Fuel consumption (T/hr)	Performance indicator (T fuel/T product)

4. Process Equipment's (Specific to Industry)

Machine name	Type	Usage	Motor capacity (kW)	Performance indicator (kWh/product)

5. Air compressors

Machine ID	Type	Serving area	Design		Motor capacity (kW)	Performance indicator (kW/cfm)
			FAD (cfm)	Pressure (kg/cm^2)		

6. Cooling towers

Tower ID	Type	Serving area	Capacity (TR)	Fan	
				(Blade material)	Motor capacity (kW)

7. Air washers

Washer ID	Type	Serving area	Capacity (TR)	Fan motor capacity (kW)

8. Refrigeration/Air-conditioning

Machine ID	Type	Serving area	Capacity (TR)	Comp. motor capacity (kW)	Performance indicator (kW/TR)

9. Pumps

Pump ID	Type	Serving area	Capacity (m^3/hr.)	Motor capacity (kW)	Performance indicator (Efficiency %)

10. Fans/Blowers

Fan no.	Type	Serving area	Capacity (m^3/hr.)	Motor capacity (kW)

11. Motor details (above 5 HP) ***

Location	Rating (H.P.)	No.	HV/LV/MV	Operating hours per day	Motor efficiency (%)

*** *Please attach separate sheet if space is found insufficient.*

12. Transformer details

Rating (kVA)	Numbers	Location	Voltage Ratio

13. Capacitor details

Rating (kVAR)	Location	Type/make	Rated voltage (volts)

14. Electric furnace details

Rating (kVA)	Type/make	Purpose	Rated voltage (volts)

15. DG Sets

Rated capacity (kVA)	Type/make	No.	Generation voltage (kV)	Average- running hours	Performance indicator (kWh/L)

16. Lighting

Area	Type of lamp	Power rating (W)	Number of fixtures	Operation (hours/day)	Method of switching

(E) RENEWABLE ENERGY POTENTIAL

1. 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)	$kWh/m^2/day$	
2. 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		

(F) WATER CONSUMPTION

1. Annual water consumption & Generation details (FY 2017-18):			
Water type	**Unit**	**Quantity**	**Expenditure (US $ /Annum)**
Drinking/Potable water	m^3		
Process water/RO water/DM water	m^3		
Sewage water generated/handled	m^3		
Cost component			
Water cost	US $		
Chemical cost	m^3/kg		
Electricity bill for water plant	US $		
Others (Please specify)			

2. Water consumption area details

Area	Type of water used	Application	Rated capacity (m^3/hr.)	Actual consumption (m^3/hr.)

Key performance indicator:

- Specific water consumption (m^3/product) of entire plant
- Specific water consumption (m^3/sub-product) of major process section in the plant

Other information:

- Use additional sheets wherever necessary

Attach following:

- Electrical single line diagram
- 12 months electricity bill
- 12 months fuel bill
- 12 months water bill
- Process flow diagram
- Machinery inventory
- List of motors
- Any other relevant information

Thank you for your co-operation in completing the questionnaire. Please ensure that all information provided is correct to best of your knowledge.

Submitted by : _ Date : _ _ _ _ _ _ _ _ _ _ _ _ _ _

Designation : _ Place : _ _ _ _ _ _ _ _ _ _ _ _ _ _