Government of Nepal

Water and Energy Commission Secretariat

Singhadurbar, Kathmandu

Energy Audit Guidelines for Domestic Appliances

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PREFACE

The Water and Energy Commission Secretariat (WECS) works in the field of collection and analysis of the energy related data in Nepal. The Energy Division of the secretariat in particular, has been doing such data collection, analysis and future planning of energy sector. With immense efforts and resources, WECS prepared National Energy Strategy in April 2013, Energy Sector Vision 2050 A.D. in November 2013 and Energy Sector Synopsis report in July 2010 respectively. In both of these documents, energy demand has been forecasted. Energy demand forecast is necessary for the future energy planning of the country.

In order to meet the energy requirement, efficient use of energy in all sectors of economy should be ensured. Keeping this in mind, WECS has prepared "Energy Audit Guidelines of Domestic sectors". This is expected to help residential sectors to reduce their energy demand by adopting energy efficient methods in their activities.

This Energy Audit Guidelines is prepared by Government of Nepal, Water and Energy Commission Secretariat (WECS). Various studies in different countries have shown that significant energy efficiency improvement opportunities exist in the residential sectors and many of which are cost-effective. These energy efficiency options include both cross-cutting as well as sector-specific measures. However, domestic sector are not always aware of energy efficiency improvement. Conducting an energy audit is one of the first steps in identifying these potentials. Even so, many households do not have the capacity to conduct an effective energy audit for their appliances. Government of Nepal-policies and programs aim to assist every household to improve competitiveness through increased energy efficiency. As technical information for improving energy efficiency; especially for domestic sector are not readily available, information on energy efficient appliances and practices should be prepared and disseminated to every household.

This Energy Audit Guideline is intended to provide step by step method for guiding energy auditors, energy managers and all stakeholders involved in energy conservation activities in domestic sector. The key elements of an energy audit, is preparing an inventory of energy using equipment and measuring energy use, analysing energy bills, benchmarking, analysing energy use patterns, identifying energy efficiency opportunities, conducting cost-benefit analysis, preparing energy audit reports, and undertaking post-audit activities. The guideline will assist energy auditors to follow systematic ways to conduct energy audit for domestic appliances without any difficulties.

SUMMARY

Energy Audit Guidelines in a domestic sector guide to conduct energy audit in a systematic way to find the saving opportunities as well as to implement identified saving options to reduce energy consumption and the cost. It also aims to raise awareness of every household members about energy efficiency and energy efficient appliances available in the domestic market as well as changes in technology. Adoption of these guidelines will help to achieve reduction in energy use and carbon emissions in a systematic way, provide framework to promote energy efficiency, identify and implement energy saving opportunities, etc. The guidelines may also be used by national institutions to recommend strategies, policies, and measures to strengthen the institutional arrangements and capacities for promoting energy efficiency.

For preparation of energy audit guidelines, energy audit of ten different domestic appliances were carried out and baseline of energy consumption were established. Those ten different domestic appliances included: Air Conditioner, Fan, Induction Heater, Lighting Fixture, Ovens, Refrigerator, Rice Cooker, Washing Machine, Water Heater and Water Pump. National, regional and global energy efficiency practices were reviewed during the study. In the urban areas, though people are educated and are aware about energy efficiency, they still use old and inefficient appliance. During the field study, people were found to be buying cheaper products and ignoring the cost of energy consumption by these inefficient appliances.

The main barrier to the adoption of energy efficiency measures identified is the lack of clear government policies and regulation. Also, the lack of institutional setup, lack of public awareness and funding are the root cause that serves as an obstacle in implementing the energy efficiency measures. To overcome these barriers, there should be well defined energy efficiency policies and financial incentives to encourage private investment in energy efficiency.

There are significant opportunities for improvement of energy efficiency through implementation of low and no cost measures. Some recommendations for specific appliances have also been provided based on the observation during the field study. With the adoption of the provided measures, appliance owners can move towards achieving energy efficiency. The guideline also includes the information sheets, formulae for calculation and outline on preparing energy audit report.

ACKNOWLEDGEMENT

Water and Energy Commission Secretariat is thankful to related domestic sectors for their involvement in the preparation of "Energy Audit Guidelines for Domestic Appliances". This study wouldn't have been possible without their cooperation.

The Secretariat is also thankful to all the team members for their contribution during field visit and preparation of this report. The Secretariat is grateful to the organizations, experts and individuals for their feedbacks and suggestions during the report preparation. Besides these, the Secretariat is also more thankful to the experts from different organizations and authors of various documents, who have been consulted during the work.

Water and Energy Commission Secretariat would like to express its sincere gratitude to GIEF Consultancy Pvt. Ltd. and the experts involved in the preparation of "Energy Audit Guidelines for Domestic Appliances".

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ABBREVIATIONS

AC & DC	-	Alternating Current & Direct Current
%	-	Percent
AC	-	Air Conditioner
AEPC	-	Alternative Energy Promotion Centre
BAS	-	Building Automation System
C	-	Celsius
CFL	-	Compact Fluorescent Lamp
CO	-	Carbon monoxide
CO_2	-	Carbon dioxide
DANIDA	-	Danish International Development Agency
EE	-	Energy Efficiency
EMR	-	Electromagnetic Radiation
ENCON	-	Energy Conservation
EnMS	-	Energy Management System
EnPI	-	Energy Performance Indicators
ESCO	-	Energy Service Company
ETFC	-	E-Trade Financial Corporation
F	-	Fahrenheit
FTL	-	Fluorescent Tube Light
GIZ	-	German International Corporation
GLS	-	General Lighting Service
GON	-	Government of Nepal
HF	-	High Frequency
HP	-	Horse Power
HPMV	-	High Pressure Mercury vapour
HPSV	-	High Pressure Sodium Vapour
Hz	-	Hertz
IDA	-	International Development Association
IEMP	-	Industrial Energy Management Project
IPPs	-	Independent Power Producers
IR	-	Infrared Radiation
IR	-	Infra-Red
ISO	-	International Organization for Standardization
KG	-	Kilogram
kVA	-	kilovolt-Ampere
kVAR	-	kilovolt-Ampere Reactive

kW	-	Kilowatt
kWh	-	kilowatt hour
L	-	Litre
LED	-	Light Emitting Diode
LPG	-	Liquefied Petroleum Gas
LPH	-	Liter Per Hour
LPSV	-	Low Pressure Sodium Vapour
M^3	-	Meter Cube
MM	-	Millimetre
MMWG	-	Millimetre Water Gauge
MOEWRI	-	Ministry of Energy, Water Resources and Irrigation
MOICS	-	Ministry of Industry, Commerce and Supplies
NEA	-	Nepal Electricity Authority
NEEAP	-	Nepal Energy Efficiency Action Plan
NEEP	-	Nepal Energy Efficiency Program
NRs/NPR	-	Nepali Rupees
O_2	-	Oxygen
OEES	-	Office for Energy Efficiency Service
PF	-	Power Factor
RE	-	Renewable Energy
RPM	-	Revolution Per Minute
S. N./ S. NO	-	Serial number
SEC	-	Specific Energy Consumption
TDS	-	Total Dissolved Solid
TV	-	Television
UNESCAP	-	United Nations Economics and Social Commission for Asia and the Pacific
UNIDO	-	United Nations Industrial Development Organization
UV	-	Ultraviolet
VA	-	Volt-Ampere
W	-	Watts
WECS	-	Water and Energy Commission Secretariat
Wh	-	Watt hours

CHAPTER 1: INTRODUCTION

1.1 Background of Energy Audit Guideline

The basic purpose of the Energy Audit Guideline is to impart knowledge to domestic sector (households) of Nepal on the benchmarking/energy auditing/performance assessment, and also to guide them on the process of identifying and implementing energy saving opportunities that may exist in domestic appliances. The guideline also aims to provide useful inputs about energy efficient equipment and technology relevant to domestic appliances.

In general, the key features of Energy Audit Guidelines for domestic sector include:

- Ways to achieve reduction in energy use and carbon emissions in a systematic way
- Providing guidance on how to benchmark, measure, document and report energy use
- Creating a clear picture of current energy use status, based on which new goals and targets can be set
- Evaluating and prioritizing the implementation of new energy-efficient technologies and measures
- Providing framework to promote energy efficiency throughout the supply chain
- Making the better use of energy consuming assets, thus identifying potentials to reduce maintenance costs or expand capacity
- Demonstrating to the stakeholders that corporate commitment to comply with their best practice to protect the environment
- Fulfilling the associated regulatory requirements and responding with confidence to green trade barriers in global market
- Provide useful inputs about energy efficient equipment and technologies available
- Identifying and implementing energy saving opportunities

The guideline provides step by step advice for appliance owners to develop strategy to identify energy efficiency opportunities and development of action plans to implement the options. The Energy Audit Guidelines may also be used by national institutions to recommend strategies, policies, and measures to strengthen the institutional arrangements and capacities of the national institutions promoting energy efficiency. These guidelines provide inputs to concerned decision-makers of national energy efficiency organizations on the path to be charted, the process to be followed, and the synergy to be created among the various stakeholders in order to realize the energy efficiency goals set by the respective governments.

The guidelines intends to present an analytical framework which can be pursued to achieve energy efficiency goals. It highlights the fact that energy efficiency promotion is a cyclic process.

1.2 Types of Energy Used in Domestic Sectors

Both electrical and thermal forms of energy are used in the domestic appliances. Electricity is supplied by Nepal Electricity Authority (NEA), a government owned organization. Major sources of thermal energy are imported from India and third country. In Nepal, petroleum products are imported and distributed by Nepal Oil Corporation (NOC). The NOC is under Ministry of Industry, Commerce and Supplies (MOICS). Mainly used liquid thermal fuel is diesel and LPG which is imported from India.

1.3 Past and Ongoing Energy Efficiency Activities in Nepal

In Nepal, study related to energy efficiency was found to be started since 1985 but the dedicated works started only from 1999 to 2005 A.D. In these years, works such as energy audits of industries, energy efficiency related trainings and increase in public awareness as well as management of loans for energy efficiency in industries were carried out. Later from 2009 to 2011 some effective works such as demand side management of electricity, energy audit, study of electricity load profile, preparation of policy suggestions for promotion of energy efficiency as well as replacement of traditional bulbs with energy efficient bulbs were done under Nepal Electricity Authority.

1.4 Policies and Legislation related to Energy Efficiency in Nepal

Article 51 (f) 3 of the constitution of Nepal has mentioned "ensuring reliable and affordable energy supply and proper utilization of energy by generation and development of renewable energy for the fulfilment of citizen's basic needs". Different acts, policies, regulations and strategy related to energy efficiency are as follows:

1.4.1 Industrial Enterprises Act, 2076

Chapter 5, Article 24 (p) of this act states that "an industry is entitled to deduction for the purpose of income tax of all expenses invested in machinery or equipment contributing to reduce consumption of energy by enhancing energy efficiency." Also 29 (b) of the same act states that "electricity generated by an industry for its own purpose is exempted from any fee or royalty payable on it under the prevailing law" and 29 (c) states that "if an industry intends to sell excess of electricity generated by it for its own purpose, it may be sold at the rate set by mutual consent under the prevailing law."

1.4.2 Industrial Policy, 2067

The objective 7.3 of Industrial policy, 2067 states that "To establish industrial entrepreneurship as a sustainable and reliable sector by utilizing latest technology and environmental friendly production process". The policies concerning to achieve the objective 7.3 are the technical and financial assistance to the industries that use environment friendly and energy saving technology on their own costs along with the special measures for the enhancement of the green industry and make the established industries free from pollution and carbon. The policy 17.11 states that "The expenses made by any industry in the machine or instrument that help to decrease the consumption of energy, the capital expenses, technology and process for the installation of a system for pollution control and less impact in environment may be deducted for the purpose of income tax" and policy 17.32 states that "No royalty shall be charged on the electricity generated by and industry for its own purpose. Moreover, if the industry desires to sell the electricity energy, provision shall be made to allow the excess energy to the national greed at the prevailing market rate."

1.4.3 National Energy Efficiency Strategy, 2075

Government of Nepal, Ministry of Energy, Water Resources and Irrigation developed and adopted the National Energy Efficiency Strategy, 2075. The average energy efficiency was 0.84% per year from 2000 to 2015 A.D. This strategy aims to double the growth rate to 1.68% by 2030. The objective is to reduce energy efficiency, facilitate energy access and energy security, and improve the balance of the environment and health.

National Energy Efficiency Strategy emphasizes the following:

- Generate awareness on energy efficiency from the consumer level to policy maker level
- Establish policy, legal and institutional frameworks for resource management, resource mobilization, infrastructure development and human resource development required for energy efficiency
- Develop national standards for energy efficiency based on the established international and regional standards as well as to develop equipment and means for measuring energy efficiency
- Make services and production cost effective and competitive by reducing energy consumption needed for production of goods and services
- Reduce energy import by energy conservation

1.4.4 Biomass Energy Strategy, 2073

The strategy aims to contribute to the sustainable development and protection of the environment by developing bioenergy, which has been used in the traditional way, as a modern, sustainable and clean energy. The following strategies are mentioned to increase the efficiency and effectiveness of the production and use of bioenergy:

- To provide technical and financial assistance for research and study on modern efficient, and affordable biomass energy technologies (biogas, ICS, gasifier, briquettes, pellets, industrial boiler, cogeneration, waste to energy etc.) for determining their feasibility, goals, quality control, emission standards, technology development and improvements.
- To carry out public awareness and promotional activities with the participation of local stakeholders for effective and efficient use of biomass energy and for expansion of modern, efficient and affordable technologies.
- To develop appropriate system and market for commercialization of biomass energy and to ensure the sales and distribution of sales of the produced biomass energy and hence benefit.

CHAPTER 2: ENERGY AUDIT AND ENERGY AUDIT METHODOLOGY

2.1 Energy Audit

An energy audit is a systematic identification of energy flow for energy conservation of any energy using entity through survey and analysis. It helps the entity/facility in understanding their energy use, recognizes the areas of high energy use, and identifies opportunities in reducing the high energy input/use without negatively affecting the output as well the quality of output. In other words, energy audit helps in identification of potential energy saving opportunities.

An energy audit is an important tool or method for finding such potentials for energy efficiency measures and for assessing their financial viability which can be carried out in different levels. Energy audit can also verify the effectiveness of energy management opportunities after they have been implemented.

Energy audit is also regarded as one of the tools of energy management system to attain the objective of improved energy performance of the organization. It may be used in conjunction with the EnMS or may be used independently. Energy audit has been defined by different institutions in different ways with more or less the common view.

- In ISO 50002:2014, Energy audits requirements with guidance for use, ISO has defined energy audit as a systematic analysis of energy use and energy consumption of audited objects, in order to identify, quantify and report on the opportunities for improved energy performance (ISO 2014).
- As per the National Energy Efficiency Strategy, 2075, Energy efficiency is the efficient use of energy by using appropriate means, technology or equipments related to energy consumption. The state of energy efficiency can be measured by the energy required to produce each good or service. The reduction of the amount of energy required per product or service by using different methods, technologies or equipments is to increase energy efficiency. The measurement of the declining rate of energy efficiency is the average state of optical energy efficiency; which refers to the declining energy consumption required to produce per national gross domestic product.

The energy audit needs to be carried out under the supervision of expert, with better understanding of energy audit making the audit more effective.

2.2 Benefits of Energy Audit

Energy Audit is the key to ‘a systematic approach for decision-making in the area of energy management’. It attempts to balance the total energy inputs with their use, and serves to identify all the energy in the domestic facility. Well carried out energy audit will always help to understand more about the energy that has been used in the appliances, and helps to identify areas where waste can occur and where scope for improvement exists.

2.3 Types of Energy Audit

There are two common types of energy audit for domestic appliances namely:

- Preliminary energy audit and
- Detailed energy audit.

a) Preliminary Energy Audit

The preliminary energy audit, also called a simple audit is the simplest and the quickest type of screening audit. This is based on visual verifications, literature review, study of installed appliances and operating data to identify any glaring areas of energy waste or inefficiency.

Typically, only major problematic high energy consumption appliances will be identified during this type of audit. Corrective measures are briefly described with saving potential, implementation cost, and simple payback periods. This level of audit is not sufficient for reaching a final decision on implementing proposed measures.

b) Detailed Energy Audit

The detailed energy audit expands on the preliminary audit described above by collecting more detailed information about the appliances as given by the manufacturers and measuring all the operating parameters at the site conduction to evaluate performance analysis of the equipment. This can be done by site measurement with energy balance to quantify actual energy used and energy wasted in various forms. It provides quantitative breakdown of the energy and evaluates energy saving opportunities so as to recommend correct measures to be taken to improve the existing efficiency of the appliances. This level of analysis can involve advanced on-site measurements and may also involve computer-based simulation tools to evaluate energy performance of the appliances. The data is then compared with the baseline as obtained from the appliance energy audit. Financial analysis is also performed for each measure considering implementation and operational cost with payback period. Sufficient details are provided to justify the investment to implement the identified options to reduce energy consumption to reduce the energy cost.

2.4 Energy Audit Methodology

An energy audit of domestic appliances is carried out by inspection, survey, measurement and analysis of energy consumption of the devices at working environment. The main aim is to reduce energy consumption and it’s cost by monitoring energy consumption and comparing it with the manufacturer's specification. Energy consumption should also be compared with the specified consumption of other similar appliances with recent/advanced technology. Audit is required to identify the most efficient and cost-effective energy conservation opportunities. Energy conservation opportunities can consist more efficient use of energy either by replacement or by modification of the existing domestic appliances. The survey consists of:

- Organizing technical data – collecting manufacturers technical data sheet, load parameters i.e., voltage, current, power factor, frequency and energy consumptions etc.
- Understanding utility rates and structures – demand charge and the cost of energy, both electrical and thermal; identifying all the energy consuming appliances, operating hours, operating procedures and the areas for potential savings.

The procedure to be followed depends upon the set criteria to conduct energy audit. The set criteria in general terms include following tasks:

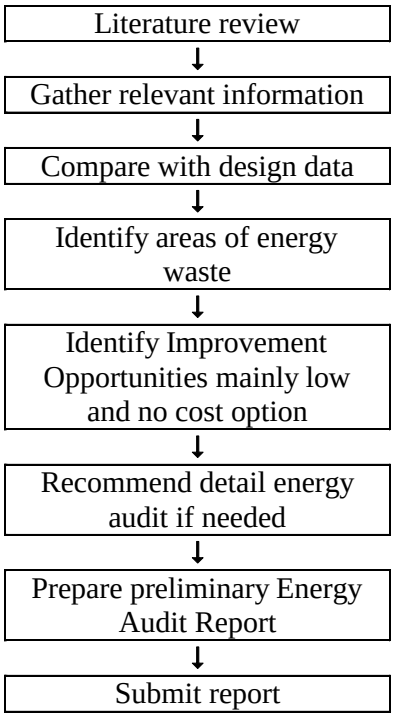
- Audit objective
- Audit type
- Audit methodology and standards
- Staff involvement
- Utility boundary
- Timeline
- Reporting requirements

2.4.1 Preliminary Energy Audit Methodology

This type of energy audit for domestic appliances uses existing or readily available data. The main objective is to compare the available data with the baseline. The following outcomes can be achieved through preliminary energy audit:

- Establish energy consumption of the appliances.
- Estimate the scope for saving.
- Identify immediate especially no cost and low cost improvements/savings.
- Set a 'reference point'.
- Identify areas for more detailed measurement to be carried out.

The flow chart for preliminary audit is as follows:



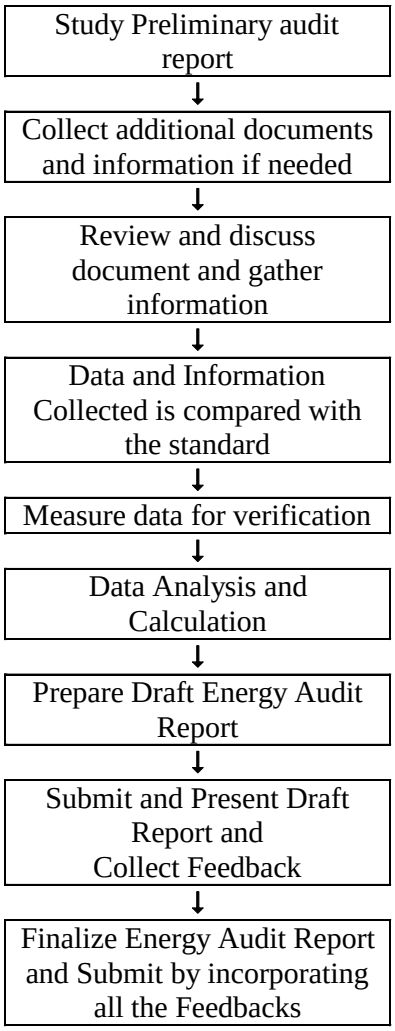
In brief we can conclude following steps to be followed for preliminary energy audit:

- Collect detail operational manual and technical specification of appliances.
- Compare the data with the design data.
- Identify existing energy loss.
- Develop energy conservation opportunities.
- Review and suggest detail energy audit, if needed.
- Report writing and submission to the client.

2.4.2 Detailed Energy Audit Methodology

Detailed energy audit methodology provides a detailed energy project implementation plan for domestic appliances, since it evaluates all major energy using systems. This type of audit offers the most accurate estimate of energy saving and cost. In detailed energy audit, one of the key elements is the energy balance of the system. This is based on an inventory of energy using appliances, its current energy consumption in the form of kerosene, diesel, petrol, LPG, wood, charcoal or electricity at current operating conditions and followed by calculation of specific energy consumption. The specific energy consumption is then compared to the value specified in the manufacturers' specification sheet (design data) and the measured data in the field.

The flow chart for detailed audit is as follows:



In brief, we can conclude following steps to be followed for detailed energy audit:

- Collect detail operational manual and technical specification of appliances.
- Organize proper Instruments & time frame to conduct experimental audit to find the performance of the existing appliances.
- Conduct Measurements by using calibrated instrument.
- Compare data measured at working condition to design value.
- Conduct few trails to verify the data for performance analysis.
- Identify existing energy loss.
- Develop Energy Conservation (ENCON) opportunities.
- Review and suggest modification if needed for appliances.
- Coordinate with the manufacturers for discussion to update new efficient technology for implementation if possible.
- Based on the measurement the techno-economically viable energy efficiency options are generated with Cost benefit Analysis.
- Report writing based on the findings.

CHAPTER 3: INTRODUCTION TO DOMESTICS APPLIANCES

Domestic appliances are machines used for routine housekeeping tasks such as cooking, washing, heating, air-conditioning, food preservation etc. Since these appliances in a home consume significant amount of energy over a period of time, it is necessary to improve their energy efficiency. Energy efficiency improvements may require changes in technology of the appliances, improved control systems or changes in user behavior.

In the early days energy prices were affordable and many consumer appliances were manufactured without consideration on energy consumption. Nowadays, major appliances are made energy efficient to lower energy consumption and operational cost. The manufacturing companies are more serious on production and supply of energy efficient appliances to compete in the global market.

3.1 Air-Conditioning System

3.1.1 General Information

Air Conditioner works in a similar way as a refrigeration unit. It is used to remove heat and moisture from any closed interior occupied space and improve the comfort of that space. A chemical refrigerant in the system absorbs the unwanted heat and pumps it through a system of piping to the outside coil. The fan, located in the outside unit, blows outside air over the hot coil, transferring heat from the refrigerant to the outdoor air. In general air conditioning systems have five mechanical components:

- a compressor
- a condenser
- an evaporator coil
- a blower
- chemical refrigerant

Depending on applications, there are several options/combinations of air-conditioners that are available for use as given below:

- Air Conditioning (for comfort / machine)
- Split air conditioners
- Fan coil units in a larger system
- Air handling units in a larger system

Types of Refrigeration:

- Vapour Compression
- Vapour Absorption

3.1.2 Available Air-conditioners in the Domestic Market

Many national and international brands of air-conditioners are available in Nepalese market. Among them, some brands are locally assembled by making use of parts imported from other countries. Domestic type air-conditioners are mainly used in offices and commercial enterprises. In Nepal, very limited quantity of air conditioners is used in domestic sector i.e. in households.

Air conditioners of capacities listed in the table below are generally available in Nepalese Market:

Table 1: Generally available capacities of ACs in domestic market

Ton	Grade	Type (Split)
0.75	Home Use	Wall Mounting
1	Home Use	Wall Mounting
1.5	Home Use	Wall Mounting
2	Home Use	Wall Mounting

3.1.3 Specific Energy Consumption

Specific energy consumption is the amount/quantity of energy consumed per unit of product or service provided by the appliances. The study of energy consumption by different brands of appliances and average SEC are given below:

Table 2: Specific energy consumption of 1.5 Ton Air Conditioner

(Air Conditioner)	Cooling Capacity (ton)	kWh consumption/ton of cooling	Average SEC: kWh/ton cooling
Brand 1	1.5	0.98	0.985
Brand 2	1.5	0.92	
Brand 3	1.5	1.16	
Brand 4	1.5	0.89	

Table 3: Specific energy consumption of 2 Ton Air Conditioner

Brand (Air Conditioner)	Cooling Capacity (ton)	kWh consumption/ton of cooling	Average SEC: kWh/ton cooling
Brand 1	2.0	0.91	0.887
Brand 2	2.0	0.86	
Brand 3	2.0	1.0	
Brand 4	2.0	0.78	

3.2 Ceiling Fan

3.2.1 General Information

A fan is a mechanical device for moving air or other gases. It uses the kinetic energy of the impellers or blades to increase the pressure of the air/gas stream which in turn moves them against the resistance of ambient (still) air.

Table 4: Specific Parameter of Ceiling Fan

Equipment	Specific Ratio	Pressure Rise (mmWg)
Fans	Up to 1.11	1136

Accordingly, fans offer a pressure rise up to 1136 mmWg and Specific Ratio up to 1.11 as shown in the table above.

As per the flow, fans are classified into two different types:

- Centrifugal flow and
- Axial flow

In centrifugal flow, airflow changes its direction twice - once when entering and second when leaving (forward curved, backward curved or inclined, radial). In axial flow, air enters and leaves the fan with no change in direction (propeller, tube axial, vane axial).

3.2.2 Available Fans in the Domestic Market

Most of the households in the region with hot and humid climate in Nepal use ceiling fans. There are various popular brands including many Chinese brands of fans available in Nepalese market.

3.2.3 Specific Energy Consumption (SEC)

Specific energy consumption is the amount/quantity of energy consumed per unit of product or service provided by the appliances. The study of energy consumption by different brands of appliances and average SEC is given below:

Table 5: Specific Energy Consumption of Ceiling Fan

Brand (Ceiling Fan)	Rated Power	Measured Power, W	Measured flow, m^3	Consumption watt/m^3	Avg. SEC: watt/m^3 of air flow
Brand 1	60	53	115	0.461	0.357
Brand 2	50	50	215	0.233	
Brand 3	60	52	110	0.473	
Brand 4	55	55	210	0.262	

3.3 Induction Heater

3.3.1 General Information

Induction heating is the process of heating an electrically conducting object, usually a metal by electromagnetic induction through heat generated in the object by eddy current. An induction heater consists of an electromagnet and an electronic oscillator that passes a high-frequency alternating current (AC) through the electromagnet. The rapidly alternating magnetic field penetrates the object, generating electric currents on the surface of the conductor, known as eddy current.

An important feature of the induction heating process is that the heat is generated inside the object itself, instead of by an external heat source via heat conduction. Thus, objects can be heated very rapidly. In addition, there need not be any external contact, which can be important where contamination is an issue. In households, it is mainly used in induction cook-tops or induction heaters for heating or cooking food in metallic vessels.

The cooking vessel must be made up of or contain ferromagnetic metals such as cast iron or stainless steel. Heat comes from within the pan, making this method of cooking a lot more efficient. It is therefore essential to ensure that cooking pans are suitable to use on an induction heater.

3.3.2 Available Induction Heater in the Domestic Market

Most of the households have induction heaters from different manufactures in present days.

3.3.3 Specific Energy Consumption (SEC)

Specific energy consumption is the amount/quantity of energy consumed per unit of product or service provided by the appliances. The study of energy consumption by different brands of appliances and average SEC is given below:

The heating load for the induction heater may infinitely vary. In this study, test was done for the load of 2 litres of water.

Table 6: Specific Energy Consumption of Induction Heater

Brand	Rated Power, W	Measured energy for boiling in Wh	Energy consumed per lit of water in Wh
Brand 1	1600	240	139
Brand 2	1600	290	
Brand 3	1600	270	
Brand 4	1600	310	

3.4 Lighting System

3.4.1 General Information

Light is a form of electromagnetic radiation (EMR). The full spectrum of EMR spans a tremendous range from cosmic rays to ultraviolet radiation to visible light to infrared heat to

radio waves, and different types of EMR differ only in their wavelength. All forms of EMR travel at the speed of light.

Light is commonly defined as the portion of the EMR spectrum that is emitted by the sun. It includes the visible portion of the spectrum that humans can see, as well as infrared (IR) radiation and ultraviolet (UV) light, both of which are invisible to the human eye. IR heat is radiated by all objects, and UV is the portion of the spectrum that is responsible for sunburn.

3.4.2 Available Lighting fixture in the Domestic Market

Table 7: Available Lighting Fixture in Nepal

Light Source	Wattage	Lumens Per Watts	Average Working Life Hours
Incandescent Lamp	15 – 1000	15	1000
Halogen	50 – 1000	25	2000
Tube Light	20 – 40 – 60 18 – 36 – 58	45-65 50-75	5000 5000
CFL	5 – 100	60-70	10000
HPMV	80 – 1000	45-50	5000
HPSV	150 – 250 – 400	110-120	10000
LPSV	35 – 70	130-175	10000
LED	1-250	70-150	50000

3.4.3 Specific Energy Consumption

Table 8: Incandescent Lamps

Brand	Rated Watt	Rated volts	Measured volts	Measured current	Measured PF	Measured Power	Measured luminous flux in lux (at 1 meter distance)
Brand 1	40	230	210	0.2	1	40	13
Brand 2	40	230	210	0.2	1	40	12
Brand 3	40	230	210	0.2	1	40	13
Brand 4	40	230	210	0.2	1	40	11

Table 9: Fluorescent tube Lamps

Brand	Rated Watt	Rated volts	Measured volts	Measured current	Measured PF	Measured Power	Measured luminous flux in lux (at 1 meter distance)
Brand 1	40	230	210	0.31	0.70	46	90
Brand 2	40	230	210	0.26	0.74	40	98
Brand 3	40	230	210	0.31	0.70	45	95
Brand 4	40	230	210	0.31	0.70	43	92

Table 10: CFL Lamps

Brand	Rated Watt	Rated volts	Measured volts	Measured current	Measured PF	Measured Power	Measured luminous flux in lux (at 1 meter distance)
Brand 1	18	230	205	0.09	0.85	17	59
Brand 2	20	230	205	0.12	0.70	18	52
Brand 3	20	230	205	0.09	0.86	17	55
Brand 4	20	230	205	0.14	0.59	17	54

Table 11: LED Lamps

Brand	Rated Watt	Rated volts	Measured volts	Measured current	Measured PF	Measured Power	Measured luminous flux in lux (at 1 meter distance)
Brand 1	10	230	205	0.05	0.85	9.5	132
Brand 2	10	230	205	0.05	0.88	9.8	135
Brand 3	10	230	205	0.05	0.86	9.5	143
Brand 4	10	230	205	0.07	0.59	9.6	112

3.5 Microwave Oven

3.5.1 General Information

An oven is a thermally insulated chamber used for the heating, baking, or drying of a substance, and most commonly used for cooking. Ovens are used in households for baking whereas in industries they are used in pottery, steel re-rolling, scrap melting and many other heating applications and are named as kiln or furnaces. It is operated generally through electric, gas, diesel, furnace oil, coal and fire wood.

Microwave oven is a type of electric oven that heats food using electromagnetic waves. Electromagnetic waves create vibrations in food particles, and the friction due to vibration

causes the food to heat up. While microwaves are known mostly as tools for reheating food, nowadays they are also used for cooking. Microwave ovens are very quick and energy efficient.

3.5.2 Available Oven in the Domestic Market

Microwave ovens of various brands are found in Nepalese market. Most of these brands are imported from India and China. There are few best brands of ovens available in Nepalese market. Branded oven comes with energy efficient technology and energy labels (Energy Star) with star ratings of 1 to 5 stars, which make the customers easy to understand about the electrical power consumption. The price range of oven varies depending upon size and brand.

3.5.3 Specific Energy Consumption (SEC)

The study of energy consumption by different brands of appliances and average SEC are given below:

The heating load for the microwave oven may infinitely vary; test was done for load of 1 litre of water that was heated from the room temperature to the boiling temperature.

Table 12: Specific Energy Consumption of Oven

Brand	Rated Power, W	Measured energy for boiling in Wh	Energy consumed per lit of water in Wh
Brand 1	1150	180	186
Brand 2	1400	165	
Brand 3	1200	198	
Brand 4	1250	202	

3.6 Pumping System

3.6.1 General Information

Pumping is the process of adding kinetic and potential energy to a liquid for the purpose of moving it from one point to another. This energy will cause the liquid to do work such as flow through a pipe or rise to a higher level. A pump transforms mechanical energy from a rotating impeller into a kinetic and potential energy required by the system. The liquid can be handled by any of the pump designs. Different pump designs could be used for different purposes.

The centrifugal pump is generally the most economical followed by rotary and reciprocating pumps. Though positive displacement pumps are generally more efficient than centrifugal pumps, the benefit of higher efficiency tends to be offset by increased maintenance cost. Worldwide, centrifugal pumps account for the majority of electricity used by pumps.

3.6.2 Available Water Pump in the Domestic Market

Most of the households use pumps ranging from 0.5 to 1 HP from various manufactures. There are various popular brands and many Chinese brands that are found in most households.

3.6.3 Specific Energy Consumption (SEC)

The study of energy consumption by different brands of pumps and their average SEC are given below:

Table 13: Specific Energy Consumption of Water Pump

Brand	Rated flow, LPH	Rated head, m	Measured flow, LPH	Measured head, m	Measured energy, wh per 1000 lit	SEC: Wh/m^3
Brand 1	1800-400	6-24	1700	9	68	83
Brand 2	16800-3000	1-11	9000	9	60	
Brand 3	4000-350	18-36	3900	9	131	
Brand 4	4200-300	10-30	4050	12	76	

3.7 Refrigerators

3.7.1 General Information

A refrigerator (fridge) is a kitchen appliance that is used to preserve the food by mechanical refrigeration. A refrigerator consists of a thermally insulated compartment and a heat pump (mechanical, electronic or chemical) that transfers heat from the inside of the fridge to its external environment so that the inside of the fridge is cooled to a temperature below the room temperature.

Refrigeration is an essential food storage technique in the developed countries. Lower temperature lowers the reproduction rate of bacteria, so the refrigerator reduces the rate of spoilage of stored food items. A refrigerator maintains temperature a few degrees above the freezing point of water. Optimum temperature range for perishable food storage is 3 to 5 °C (37 to 41 °F). A similar device that maintains temperature below the freezing point of water is called a freezer.

3.7.2 Available Refrigerators in the Domestic Market

Refrigerators (Fridges) of various brands are found in Nepalese market, among which some brands of refrigerator are assembled in Nepal. The brands of refrigerators which are made in Nepal are generally assembled in Nepal by importing components from India and China. Branded refrigerators come with energy efficient technology and energy labels, (Energy Star) with star ratings of 3 to 5 star, which makes customers easy to understand about the electrical power consumption.

3.7.3 Specific Energy Consumption

Specific energy consumption is the amount/quantity of energy consumed per unit of product or service provided by the appliances. The study of energy consumption by different brands of appliances and average SEC are given below. Energy consumption was measured for the same load (12 litres of water at 24 degree C) in the refrigerator. Temperature setting was at 5 deg C.

Table 14: Specific Energy Consumption of Refrigerator

Brand	Rated Volume, lit	Rated Power, W	Measured energy per hour in Wh	Energy consumed Wh/lit volume
Brand 1	310	114	80	0.258
Brand 2	289	105	52	0.180
Brand 3	336	130	71.5	0.213
Brand 4	243	110	65	0.193

3.8 Rice cooker

3.8.1 General Information

Rice cooker is an automated electric kitchen appliance which is designed to boil or steam rice. Rice cooker is also known as rice steamer. Rice cooker consists of three major parts; a heat source, a cooking bowl and a thermostat. Heat source is an electrical resistance heater, bowl is a vessel for placing rice and water, and thermostat is a temperature control device.

3.8.2 Available Rice Cooker in the Domestic Market

Rice cooker of various brands are found in Nepalese market, among which some brands are assembled in Nepal. Branded rice cookers come with energy efficient technology and energy guide labels, (Energy Star) with star ratings of 3 to 5 stars. This enables customers to know about the electrical power consumption of the cooker.

3.8.3 Specific Energy Consumption (SEC)

Specific energy consumption is the amount/quantity of energy consumed per unit of product or service provided by the appliances. The study of energy consumption by different brands of appliances and average SEC are given below. Test was carried out by boiling three litres of water at room temperature.

Table 15: Specific Energy Consumption of Rice Cooker

Brand	Rated Power, W	Measured energy, Wh	Energy consumed per lit	Energy consumed per lit of food in Wh
Brand 1	1300	375	125	124.5
Brand 2	1650	390	130	
Brand 3	1250	360	120	
Brand 4	1400	370	123	

3.9 Washing Machine

3.9.1 General Information

A washing machine (laundry machine, clothes washer, or washer) is a home appliance used to wash laundry. The term is mostly applied to machines that use water as opposed to dry

cleaning (which uses alternative cleaning fluids and is performed by specialist businesses) or ultrasonic cleaners. The user adds laundry detergent, which is sold in liquid or powder form, to the wash water.

3.9.2 Available washing machine in the Domestic Market

Washing Machines of various brands are found in Nepalese market, among which some brands are assembled in Nepal. Washing machines are assembled in Nepal generally by importing components from India and China. Branded washing machines come with energy efficient technology and energy guide labels, (Energy Star) with star ratings of 3 to 5 stars that enable customers to understand about the electrical power consumption.

3.9.3 Specific Energy Consumption

Specific energy consumption is the amount/quantity of energy consumed per unit of product or service provided by the appliances. The study of energy consumption by different brands of appliances and average SEC are given below. During the study, same volume of clothes (5 kg) was washed for the same duration.

Table 16: Specific Energy Consumption of Washing Machine

Brand	Wash Capacity, kg	Rated wash power, W	Measured energy per cycle, Wh	Avg. SEC per cycle, Wh
Brand 1	8	2050	730	827.5
Brand 2	8	2250	880	
Brand 3	7.5	2100	890	
Brand 4	8	2400	810	

3.10 Water Heater

3.10.1 General Information

Water heating is a heat transfer process that uses an energy source to heat water above its initial temperature. Typical domestic uses of hot water include cooking, cleaning, bathing, and space heating. In this study, electrical water heater generally known as electric geyser is considered.

Electric geyser is an appliance that uses heating element or copper coil inside it to convert electricity to heat energy. Heating element is situated inside the water tank. In order to reduce the heat loss, high-efficiency units feature additional insulation.

3.10.2 Available Water heater in the Domestic Market

Most of the household electric geysers have 1 to 3 kW heaters used in them and depends on the volume of water they hold. Various popular brands of water heater are found in Nepalese market.

3.10.3 Specific Energy Consumption

Specific energy consumption is the amount/quantity of energy consumed per unit of product or service provided by the appliances. The study of energy consumption by different brands of appliances and average SEC is given below. Study was carried out by heating a quantity of water from 26^{o} C to 45 ^{o} C.

Table 17: Specific Energy Consumption of Water Heater

Brand	Capacity, lit	Rated Power, Watt	Measured energy in Wh	Energy consumption Wh/lit/oC	SEC: Wh/lit/ ^{o}C
Brand 1	35	2200	805	1.21	1.43
Brand 2	35	2200	795	1.20	
Brand 3	25	2000	780	1.64	
Brand 4	25	2000	790	1.66	

CHAPTER 4 – ENERGY EFFICIENCY OPPORTUNITIES

4.1 Air-Conditioning System

4.1.1 Check List for Energy Audit: Air Conditioner

- Measure electrical parameters such as voltage, current, power factor, Watts, kWh by using electrical power analyzer/data logger for one hour.
- Measure humidity, dry and wet bulb temperature of outlet and inlet air from/to the conditioned space by using hygrometer
- Measure air flow rate
- Calculate the cooling achieved from the above data (calculation sheet in Annex- 2)
- Calculate the EER and investigate for causes of deviation from the designed EER.
- Check filters and insulation on refrigerant line.
- Collect and refer the manual as well as specification of the star rated air-conditioner and review best available technologies, i.e. inverter based system etc. and recommend for upgrades.

4.1.2 Energy Saving Opportunities

Following are the important energy saving opportunities in domestic air-conditioners:

- Use as much natural air as possible through air circulation.
- Tune up the control system i.e. Switch off the air-conditioning unit when no one is in the room or acquire automatic switching mechanism.
- Use sealed windows and curtains to block the sunlight to reduce room temperatures and reduce the amount of workload to the air conditioner unit.
- Remove unneeded lamps or heating loads when air-conditioning is in operation during summer.
- Install low power lamps (LED) in room so as to reduce heat load
- Use timer while sleeping at night so it should be off when not needed especially in the morning.
- Try not to wear tight and dark color cloths at home. Loose and light color clothes allow reducing minimum set temperature ultimately saving the energy.
- Ensure rooms are air tight and without any vents. It will prevent the loss of cool air.
- Rearrange furniture setup in room if that obstructs the air conditioning vents.
- Provision of ceiling fan in room will reduce the load of air conditioner in case of initial phase and slightly hotter weather.
- Consider installing a building automation system (BAS) for optimal operation.

- Use appropriate thermostat setting.
- Check filters on a schedule (at least monthly) and clean/change if appropriate.
- Consider reducing ceiling heights, if it is very high.
- Eliminate obstructions in front of the radiators, baseboard heaters, etc.

4.2 Ceiling Fan

4.2.1 Check List for Energy Audit: Ceiling Fan

- Measure electrical parameters such as voltage, current, power factor, Watts, by using electrical power logger.
- Measure air flow by using anemometer
- Calculate airflow using above data and derive watts/m3 of air moved (calculation sheet in Annex-3)
- Compare with the design value and investigate for the causes of deviation
- Check the mode of operation and speed control mechanism
- Check temperature of the motor by using IR temperature gun for excessive heating
- Collect and refer the manual as well as specification of the star rated fan and review best available technologies, i.e. super fan etc. and recommend for upgrades.

4.2.2 Energy Saving Opportunities

Following are the important energy saving opportunities in Ceiling Fans:

- Replace ordinary fan with super fan and star rated fans.
- Replace resistive fan regulator with electronic regulator.
- Switch off fan when it is not needed.
- Minimize fan inlet and outlet obstructions.
- Minimize fan speed.
- Use aero-foil shaped fan blades.

4.3 Induction Heater

4.3.1 Check List for Energy Audit: Induction Heater

- Measure electrical parameters such as voltage, current, power factor, power and energy by using electrical power logger.
- Heat given quantity of water or sample product and measure corresponding energy consumption.
- Compare measured energy consumption (calculation sheet in Annex-4), with the design value and investigate for deviation, if any.

- Collect and refer the available manual as well as specifications of the star rated heaters and review the best available technologies and recommend for improvement.

4.3.2 Energy Saving Opportunities

Following are the important energy saving opportunities in induction heaters:

- Use proper cooking utensils with proper size.
- The tempered glass surface on top of the heater should be cleaned regularly.
- Use star rated energy efficient induction heaters.
- Compare measured energy consumption (calculation sheet in Annex-4) with the design value and investigate for causes of deviation, if any.
- Make habit of using efficient induction appliances and avoid other conventional heating energy sources.
- Select required power setting while cooking.
- Always refer manual as instructed by suppliers.

4.4 Lighting Fixtures

4.4.1 Check List for Energy Audit: Lighting

- Measure electrical parameters such as voltage, current, power factor, power and energy by using electrical power logger.
- Measure illumination level in lux at appropriate distance by using lux meter.
- Compare measured energy consumption and lux level with the design value and investigate for deviation, if any.
- Collect and refer the available manual as well as specification of the star rated lamps and review the best available technologies and recommend for improvement.

4.4.2 Energy Saving Opportunities

Following are the important energy saving opportunities in lighting fixtures (lamps):

- Use as much natural light as possible by using translucent sheets or placing working station near windows during the day time.
- Switch off the lights when no one is in the room. If possible, acquire automatic switching apparatus.
- Control lighting with clock timers, delay timers, photocells, occupancy sensors or have separate switching mechanism.
- Replace GLS and CFL with LED lamps.
- Install efficient lighting and consider efficiency (lumens/watt) of various technologies ranging from the best to the worst.

- Reduce excessive illumination level to the standard level using switching or de-lamping.
- Remove unnecessary lamps where lighting levels are too high.
- Clean luminaries, ceilings, walls etc. on a regular basis.
- The work surface area should be painted with light color for efficient use.
- Reduce background light levels and focus more on task lighting i.e. concentrate light just where it is needed by keeping ceiling lights turned off and by using table or floor lamps.
- Install metal halide lamps in place of mercury/sodium vapour lamps for outdoor lighting.
- Install High Pressure Sodium Vapour (HPSV) lamps for applications where color rendering is not critical.
- Install high frequency (HF) electronic ballasts in place of conventional ballasts.

4.5 Microwave Oven

4.5.1 Check List for Energy Audit: Microwave Oven

- Measure electrical parameters such as voltage, current, power factor, power and energy by using electrical power logger.
- Heat given quantity of water or sample product and measure corresponding energy consumption.
- Compare measured energy consumption (calculation sheet in Annex-6) with the design value and investigate causes for deviation, if any.
- Collect and refer the available manual as well as specification of the star rated heaters and review the best available technologies and recommend for improvement.

4.5.2 Energy Saving Opportunities

Following are the important energy saving opportunities in microwave ovens:

- Make habit of using efficient oven by avoiding other conventional heating energy sources.
- Use of ceramic or glass pans will reduce oven temperature 10 to 14°C lower than that of regular metal pans to cook the same food.
- Improve air circulation; food cooks more efficiently in ovens where the air can circulate freely.
- Avoid opening the door while baking; each time the door is opened, about 20% of the heat is lost. Using an oven timer will help you avoid opening the door to check on the food.
- Insulate and seal every part of the oven to prevent heat loss.

- Check oven temperature regularly by using a separate oven thermometer to ensure that the oven control is accurate.
- Use star rated energy efficient oven.
- Purchase efficient and quality product i.e. oven.
- Set time as per the requirement.
- Set required temperature while baking.
- Use appropriate utensils i.e. Use ceramic or glass pans.

4.6 Pumping System

4.6.1 Check List for Energy Audit: Pump

- Measure electrical parameters such as voltage, current, power factor, power and energy by using electrical data logger for a given period of time.
- Measure water flow by using flow meter or measure time taken to collect volume of water by using stop watch.
- Measure the head of the water to be pumped.
- Calculate the hydraulic power, pump efficiency and overall efficiency and compare it with the design value (calculation sheets in Annex-11).
- Compare measured and calculated values with the design value and investigate causes of deviation.
- Collect and refer the available manual as well as specification of the star rated pumps and review the best available technologies and recommend for improvement.

4.6.2 Energy Saving Opportunities

Following are the important energy saving opportunities in domestic water pumps:

- Use star rated and energy efficient pump.
- Ensure adequate NPSH at site of installation.
- In the case of oversized pump, downsize or replace impeller or replace with correct sized pump for efficient operation.
- Ensure availability of basic instruments at pumps such as pressure gauges, flow meters etc. for regular monitoring.
- Operate pumps near the best efficiency point.
- Avoid pump throttling by means of proper design.
- Reduce system resistance by pressure drop assessment and pipe size optimization.
- Stop idle running of the pump.
- Repair seals and packing to minimize water waste.

4.7 Refrigerators

4.7.1 Check List for Energy Audit: Refrigerator

- Measure electrical parameters such as voltage, current, power factor, power and energy by using electrical data logger for a given period of time.
- Operate the refrigerator for one hour with specified load as recommended by the manufacturer.
- Measure energy consumption for one hour (calculation sheet in Annex-7) and compare it with the design value.
- In case of deviation in the measured energy consumption and design energy consumption, investigate causes for the deviation.
- Collect and refer the available manual as well as specification of the star rated refrigerators and review the best available technologies and recommend for improvement.

4.7.2 Energy Saving Opportunities

Following are the important energy saving opportunities in household refrigerators:

- Don’t place hot food, always place cold food in the refrigerator.
- Defrost the freezer compartment and food inside the refrigerator.
- Check door seals regularly and close the door properly. Beware: always close the door without delay.
- Always buy a star rated energy efficient refrigerator.
- Track temperature. Refrigerator shouldn’t be set any lower than 5^{o} C, while freezer should be -18^{o} C.
- Check the condenser coils for dust.
- Use door ice makers and water dispensers to reduce the need to open the door, which helps maintain a more constant temperature though these convenient items will increase your refrigerator's energy use by 14 to 20 percent.
- Consider your family’s needs, and get the right size. Fridges come in many different sizes, but the most energy-efficient refrigerators are usually 16-20 cubic feet.
- Measure the space for the fridge: Leave at least 1 inch clearance around the unit for adequate airflow.

4.8 Rice cooker

4.8.1 Check List for Energy Audit: Rice Cooker

- Measure electrical parameters such as voltage, current, power factor, power and energy by using electrical power logger.

- Heat given quantity of water or sample product and measure corresponding energy consumption.
- Compare measured energy consumption (calculation sheet in Annex-8) with the design value and investigate cause for deviation, if any.
- Collect and refer the available manual as well as specification of the star rated rice cookers and review the best available technologies and recommend for improvement.

4.8.2 Energy Saving Opportunities

Following are the important energy saving opportunities in rice cookers:

- Choose the appropriate size of rice cooker fit for the requirement of your family. An oversized rice cooker will consume more energy than an optimally sized rice cooker.
- Ensure that the cooker cover is firmly in place.
- Utilize the 'Keep Warm' function if the rice can't be consumed right away as it will maintain the appropriate amount of heat needed to keep the rice warm but it is always the best to unplug after use to prevent additional consumption.
- Clean your rice cookers and make sure that the inner pot and hot plate are free from any form of impurities such as burnt grains of rice or hardened food to ensure efficient and even heating.
- Soak rice in water for about half an hour before cooking.
- Use the right amount water for rice cooking, which is usually recommended in rice cooker manual. In case you don't have the manual at hand, it is recommended that the total volume of water and rice is about double of the volume of rice.

4.9 Washing Machine

4.9.1 Check List for Energy Audit: Washing Machine

- Measure electrical parameters such as voltage, current, power factor, power and energy by using electrical data logger for a given period of time.
- Operate the washing machine for one cycle with specified load as recommended by the manufacturer.
- Measure energy consumption for a complete cycle (calculation sheet in Annex-9) and compare it with the design value.
- In case of deviation in the measured energy consumption and design energy consumption, investigate causes for the deviation.
- Collect and refer the available manual as well as specification of the star rated washing machines and review the best available technologies and recommend for improvement.

4.9.2 Energy Saving Opportunities

Following are the important energy saving opportunities in washing machines:

- Pre-soak stains; soak your stains in cold water for at least half an hour before washing, use stain remover if applicable.
- Run your washing machines in shortest cycle i.e. fast wash or eco wash.
- Switch off the power when the washing machine is not use.
- Choose energy efficient star rated washing machines.
- User appropriate size and required feature of the machine.
- Use warm water for washing dirty cloth.
- Wait for full load; washing machines use the same amount of mechanical energy, no matter how big the load is.

4.10 Water Heater

4.10.1 Check List for Energy Audit: Water Heater

- Measure electrical parameters such as voltage, current, power factor, power and energy by using electrical data logger for one cycle. Water volume, input water temperature, cut-off temperature should be as specified in the manufacturer's specification.
- Measure energy consumption for one cycle (calculation sheet in Annex-10) and compare with the design value.
- In case of deviation in measured energy consumption and design energy consumption, investigate causes for the deviation.
- Collect and refer the available manual as well as specification of the star rated water heater and review the best available technologies and recommend for improvement.
- Check for heat loss from the heater surface.

4.10.2 Energy Saving Opportunities

Following are the important energy saving opportunities in water heater:

- Replacing existing low efficient water heater with an energy efficient star rated product.
- Replace conventional electric resistance water heaters with heat pumps, if possible.
- Replace tank storage water heater with tank less instantaneous water heater.
- Insulate naked pipeline and tank to minimize heat loss.
- Replace conventional water heater with a non-conventional solar vacuum tube water heater.
- Compare the quality and features of the equipment before purchasing and always select appropriate energy efficient star rated water heater.
- Select required temperature while heating.

- Use efficient and renewable source of heating rather than conventional source for heating water.
- Use water heater of appropriate capacity.

Annexes

Annex 1: Energy Audit Equipment Details

The requirement for an energy audit such as identification and quantification of energy necessitates measurements. These measurements require use of instruments. These instruments must be portable, durable, easy to operate and relatively inexpensive. The parameters generally monitored during energy audit may include the following:

Basic Electrical Parameters in AC system: Voltage (V), Current (I), Power Factor (PF), Active, Power (kW), Apparent Power (demand) (kVA), Reactive Power, Energy Consumption (kWh), Frequency (Hz), Harmonics etc.

Basic Electrical Parameters in DC system: Voltage (V), Current (I), Power (kW), Energy Consumption (kWh) etc.

Parameters of importance other than electrical are: temperature & heat flow, radiation, air and gas flow, liquid flow, revolution per minute (RPM), air velocity, noise and vibration, dust concentration, total dissolved solid (TDS), pH, moisture content, relative humidity, flue gas analysis – carbon dioxide, oxygen, carbon monoxide, oxides of sulphur, oxides of nitrogen, combustion efficiency etc.

The following energy monitoring/measuring equipment is needed to conduct energy audit in Domestic Sectors:

SN	Equipment Used	Image	To Measure
1.	Data Logger/ Electrical Power Analyzer		Record and measure the electrical parameters such as Amps, Volts, Frequency, PF, kW, kVA, kVAr, harmonics etc
2.	Electrical clamp-on meter		Used to measure electrical parameters such as Amps and Volts, PF, kW, frequency, etc.
3.	Temperature gun		To measure temperature parameters

SN	Equipment Used	Image	To Measure
4.	Lux Meter		To measure intensity of Light.
5.	Pressure Gauge		To measure pressure
6.	Anemometer		To measure Air and Gas Velocity
7.	Leak detector		To identify leakage
8.	Contact Thermometer		To measure surface temperature
9.	Stroboscope		To measure rotational speed

SN	Equipment Used	Image	To Measure
10.	Flow meter		To measure water flow
11.	Digital Camera		To capture temperature profile picture
12.	Stop Watch		To measure Time
13.	Sling Hygrometer		To measure Dry bulb and Wet bulb temperature
14.	Digital Temperature & Hygrometer		To measure temperature & humidity

Annex 2: Data Collection and Calculation Sheet for Air Conditioner

Make	**Value**
Model	
Rated Volts, V	
Rated Current, A	
Rated Cooling Capacity, Watts	
Rated Cooling input, Watts	
Rated EER	
Measured input, Watts	
Area for air flow, m^2	
Measured air speed, m/s	
Outlet air (from space) DBT, ^oC	
Outlet air WBT, ^oC	
Enthalpy of outlet air, kJ/kg	
inlet to space air DBT,^oC	
inlet air WBT, ^oC	
Sp. Weight, kg/m^3	
Enthalpy of inlet air, kJ/kg	
Time in hours	
Calculated cooling capacity, w = area*air speed*time in seconds*air specific weight *enthalpy* calorie to watt hour conversion factor/4.18	
Calculated EER = Cooling in watts/power consumption in watts	
kWh/ton = Measured input, Watts/ Calculated cooling capacity, ton	

Annex 3: Data Collection and Calculation Sheet for Ceiling Fan

Make	Value
Model	
Sweep	
Rated Volts, V	
Rated Current, A	
Rated power, Watts	
Rated flow, m3/Watts	
Measured Volts, V	
Measured Current, A	
Measured power, Watts	
Measured air speed in meter	
Measured area in m2	
Measured flow, m3 = Measured air speed in meter * Measured area in m2	
Measured flow/watt = Measured flow, m3/ Measured power, Watts	

Annex 4: Data Collection and Calculation Sheet for Induction Heater

Make	Value
Model	
Rated Volts, V	
Rated Current, A	
Rated power, Watts	
Measured Volts, V	
Measured Current, A	
Measured power, Watts	
Measured pf	
Time	
Measured energy in wh = measured watt * time in hours Measured energy consumption per litre = measured energy, wh/volume of water heated in liter	

Annex 5: Data Collection and Calculation Sheet for Lighting

Make	Value
Type	
Rated Volts, V	
Rated Current, A	
Rated power, Watts	
Measured Volts, V	
Measured Current, A	
Measured power, Watts	
Measured luminous flux in lux (from the lux meter reading)	

Annex 6: Data Collection and Calculation Sheet for Oven

Make	Value
Model	
Rated Volts, V	
Rated Current, A	
Rated power, Watts	
Measured Volts, V	
Measured Current, A	
Measured power, Watts	
Measured pf	
Time	
Measured energy in wh = measured watt * time in hours	
Measured energy consumption per litre = measured energy, wh/volume of water heated in liter	

Annex 7: Data Collection and Calculation Sheet for Refrigerator

Make	Value
Model	
Type	
Refrigerant	
Volume, lit	
Rated Volts, V	
Rated Current, A	
Rated power, Watts	
Measured Volts, V	
Measured Current, A	
Measured power, Watts	
Measured pf	
Time	
Measured energy in Wh = Measured power, Watts * Time in hours	

Annex 8: Data Collection and Calculation Sheet for Rice Cooker

Make	Value
Model	
Rated Volts, V	
Rated Current, A	
Rated power, Watts	
Measured Volts, V	
Measured Current, A	
Measured power, Watts	
Measured pf	
Time	
Measured energy in Wh = Measured power, Watts * Time in hours	

Annex 9: Data Collection and Calculation Sheet for Washing Machine

Make	**Value**
Model	
Type	
Volume	
Rated Volts, V	
Rated Current, A	
Rated power, Watts	
Measured Volts, V	
Measured Current, A	
Measured power, Watts	
Measured pf	
Time	
Measured energy in Wh = Measured power, Watts * Time in hours	

Annex 10: Data Collection and Calculation Sheet for Water Heater

Make	Value
Type	
Rated capacity in lit	
Rated max temp	
Rated max pressure	
Rated Volts, V	
Rated Current, A	
Rated power, Watts	
Measured Volts, V	
Measured Current, A	
Measured power, Watts	
Measured pf	
Measured temperature rise ^{o}C Measured Energy = Measured power, Watts * time in hours Measured kWh/lit/^{o}C = Measured Energy in Wh/water volume in lit/temperature rise in ^{o}C	

Annex 11: Data Collection and Calculation Sheet for Pump

Make	Value
Model	
Rated Flow	
Rated head	
Rated Volts, V	
Rated Current, A	
Rated power, Watts	
Measured Volts, V	
Measured Current, A	
Measured power, Watts	
Measured head Hydraulic Power: Q (flow in m3/sec)*H (head in m) *ρ (density in kg/m3)* g (m/sec2) Overall efficiency (hydraulic power/motor input power) Pump efficiency (overall efficiency/motor efficiency)	

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