Draft Energy conservation guidelines for industries: Category-A

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Bureau of Energy Efficiency

Contents

List of tables

List of abbreviations

AAS	Actual Air Supplied
BOP	Best Operating Point
BFP	Boiler Feedwater Pump
CO	Carbon Monoxide
DC	Designated Consumer
DG	Diesel Generator
EC	Energy Conservation
ECBC	Energy Conservation Building Code
EM	Energy Management
ESCOs	Energy Service Companies
FRP	Fibre-reinforced plastic
GAIL	Gas Authority (India) Limited
GCV	Gross Calorific Value
HT	High Tension
HVAC	Heating, Ventilation and Air Conditioning
IBR	Indian Boiler Regulation
IEMS	Industry Energy Management Systems
IS	Indian Standards
ISO	International Organization for Standardization
kCal	Kilo Calorie
kWh	Kilo Watt-hour
LED	Light Emitting Diode
LPD	Lighting Power Density
LPG	Liquefied Petroleum Gas
M&V	Monitoring and Verification
NAPCC	National Action Plan on Climate Change
NG	Natural Gas
NMEEE	National Mission for Enhanced Energy Efficiency
NPSH	Net Positive Suction Head
O_2	Oxygen
OEM	Original Equipment Manufacturer
pf	Power Factor
PAT	Perform, Achieve and Trade
SCADA	Supervisory Control And Data Acquisition
SEC	Specific Energy Consumption

SME	Small and Medium Enterprise
SPC	Specific Power Consumption
SPV	Solar Photo Voltaic
STP	Standard Temperature and Pressure
TFH	Thermic Fluid Heater
VFD	Variable Frequency Drive
WHR	Waste Heat Recovery

List of definitions

In the Energy Conservation Guidelines as herein defined where the context so admits, the following words and expression will have the meaning as specified:

Accredited energy auditing firm

The accredited energy auditing firm refers to the firm that has been empanelled by BEE to undertake activities in DCs as prescribed under EC Act.

Certified energy manager

Energy manager means any individual possessing the qualifications prescribed under clause (m) of section 14 of Energy Conservation Act (2001). The certified energy manager refers to the person having qualified the national certification examination for certified energy manager and energy auditor conducted by the Bureau of Energy Efficiency (BEE). A candidate qualifying as certified energy auditor automatically qualifies for certified energy manager as well. Such persons can be considered by the DCs for appointment or designated as energy manager under the EC Act.

Designated consumer

The designated consumer (DC) means any consumer specified under clause (e) of section 14 of Energy Conservation Act (2001). For the purpose of the EC Guidelines, the following industries are covered; (1) aluminium, (2) fertilizers, (3) iron and steel, (4) cement, (5) pulp and paper, (6) chlor alkali, (7) textile, (8) petrochemicals, (9) petroleum refineries, and (10) thermal power stations having threshold limit for energy consumption as specified by EC Act (2001) time to time.

Energy Service Companies

Energy Service Companies (ESCOs) is a company that offers energy services, usually design, retrofitting and implementation of energy efficiency projects after identifying energy saving opportunities through energy audit of existing facilities, energy infrastructure outsourcing, power generation and energy supply, financing or assist host entities in arranging finances for energy efficiency projects by providing a savings guarantee, risk management in the implementation of the energy efficiency projects and also perform

measurement and verification (M&V) activities to quantify actual energy savings post implementation of energy efficiency projects."

Standards

Standards are optimum performance values achieved by an energy consuming utility in daily operation.

State designated agency

The state designated agencies (SDAs) are the organisations identified by the State Governments, in consultation with BEE under the provisions of the EC Act, 2001 to coordinate, regulate and enforce the efficient use of energy and its conservation at state level.

STP conditions

STP is defined as a temperature of 273.15 K (0 °C, 32 °F) and an absolute pressure of exactly 105 Pa (100 kPa, 1 bar).

Targets

Targets are equal to the best achievable values of an energy consuming utility in daily operation.

1.0 Background

The Energy Conservation (EC) Act, 2001 provides for efficient use of energy and its conservation in India. The Government of India set up Bureau of Energy Efficiency (BEE) under the provisions of the EC Act. The mission of BEE is to assist in developing policies and strategies with a thrust on self-regulation and market principles, within the overall framework of the EC Act with the primary objective of reducing energy intensity of the Indian economy. The Bureau of Energy Efficiency coordinates with designated consumers, designated agencies and other organizations and recognizes, identifies and utilizes the existing resources and infrastructure, in performing the functions assigned to it under the Energy Conservation Act. The Act provides for regulatory and promotional functions of the Bureau. The Energy Conservation Act provides a list of energy intensive industries and other establishments specified as designated consumers (DCs).

One of the flagship programmes of Bureau of Energy Efficiency is Perform, Achieve and Trade (PAT) scheme towards enhancing energy efficiency in Indian industrial sector in general and Designated Consumers (DCs) in particular. The PAT scheme was formed under the National Mission for Enhanced Energy Efficiency (NMEEE). The NMEEE is one of the eight national missions under the National Action Plan on Climate Change (NAPCC) launched by the Government of India in the year 2008.

The Bureau has envisaged that the smooth implementation of PAT scheme can be enhanced and strengthened by formulating and making available a suitable "Energy Conservation Guidelines" (EC Guidelines) for the targeted industry sub-sectors.

Japan is one of the pioneers in implementing energy efficiency at global level. As part of their energy efficiency efforts, the Government of Japan had introduced energy conservation guidelines to support industries to improve energy performance. Looking at their success, the Government of India, on similar lines, has also prepared Energy Conservation Guidelines for different categories of industries operating in India as shown in table 1.1.

Table 1.1: Different categories of industries covered under EC guidelines

Category	Details
Category –A	Designated consumers (DCs) covered under PAT scheme but limited to the following industries: (1) Aluminium, (2) Cement, (3) Chlor alkali, (4) Fertilizers, (5) Iron and steel, (6) Petrochemicals, (7) Petroleum refineries covering only cracker units, (8) Pulp and paper, (9) Textile and (10) Thermal power stations
Category–B	Large industries having energy consumption of less than existing minimum threshold limits for designated consumers
Category –C	Small scale enterprises with energy costs accounting for more than 30% of total production cost but limited to the following SME sectors: (1) Glass, (2) Foundry, (3) Forging, (4) Ceramics, (5) Dairy and (6) Textile industries.
Group–D	Medium enterprises with energy costs accounting for 10% to 30% of total production costs but limited to the following sectors: (1) Brick, (2) Hand Tools, (3) Food, and (4) Limestone industries.
Group–E	Micro industries having material cost more significant than energy cost

2.0 Objectives

The overall objective of the energy conservation guidelines for large industries and SMEs is to guide the management and operators in large industries and SMEs to manage energy consumption by standardizing the energy performance values of various energy consuming equipment and systems deployed for manufacturing process.

One of the important components under the overarching framework of the energy conservation guidelines is benchmarking of standard energy performance values and a procedure for establishing target energy performance values for major energy consuming equipment such as boiler, furnace, thermic fluid heater, waste heat recovery equipment, motor, etc.

The objective of this document is to provide energy conservation guidelines to large industries that are covered as "designated consumers" (DCs) under PAT mechanism of EC Act, 2001 but limited to the list as provided in Section 1, hereafter called Category-A industries.

3.0 Methodology

3.1 Activities followed for preparation of EC guidelines

A review of the Energy Conservation Guidelines pertaining to industries in Japan was carried out to draw blue print of draft Energy Conservation Guidelines applicable for Indian industries. Relevant secondary data from different industries were collated through questionnaire survey and field visits undertaken to industries. Other sources of secondary data include (i) performance audits and sectoral study reports (ii) original equipment manufacturers, (iii) industries, (iv) sectoral experts, (v) stakeholder consultations with industries and industry associations and (vi) secondary sources such as relevant websites. Interactions with industry personnel and industry associations were carried out to understand key operating parameters in different utilities. Further discussions were held with original equipment manufacturers (OEMs) and sectoral experts in India and Japan to ascertain the relevance of data collated for different utilities.

A detailed data analysis of relevant parameters of various utilities in industries were carried out using statistical tools to benchmark key operating parameters as "Standard value" and "Target value". These parameters include air ratio, flue gas temperature, surface temperature, level of waste heat recovery (WHR), efficiency of motors, efficiency of fans, corrected target power factor of electrical equipment, lighting power density, etc. The average values and standard deviations of the data samples of similar groupings were arrived at through data analysis. The collated data were sanitized to exclude extremely higher or lower values for the purpose of analysis.

The preparation of EC Guidelines had considered existing technology standards and practices of various industry sub-sectors in India. The draft Energy Conservation Guidelines were presented in a stakeholder workshop in which representatives from industries, industry associations, original equipment suppliers, sectoral experts, etc. participated and provided their inputs. The revised Energy Conservation Guidelines were again presented in a second stakeholder workshop to ensure synergy with the industry. With these inputs, the EC Guidelines were finalised for Category-A industries.

The "Standard Values" of an energy consuming utility include optimum performance values which are achieved by the industry under daily routine operations. The "Target Values" of the utility represent better performance values than standard values. These values focus essentially on those bench marks, which shall guide the industry to improve the performance of existing facilities, new installations and retrofits in the existing facilities. An empirical equation was considered to arrive at standard values and target values using average and standard deviation of the data samples, which are discussed below.

3.2 Evaluation of standard and target values

3.2.1 Standard values

The standard values are arrived at using the following equation.

Standard value = Average value of the data samples

A nominal tolerance of +2.5% to -2.5% of Standard value is considered to accommodate variations in performance of the utilities within the range of standard values.

Upper limit = Standard value + 2.5% of Standard value
Lower limit = Standard value – 2.5% of Standard value

3.2.2 Target values

The target values are arrived at using the following equation.

Target = Average value of the data samples – Standard deviation of the data series

A nominal tolerance of +2.5% to -2.5% of Target value is considered to accommodate variations in performance of the utilities within the range of target values.

Upper limit = Target value + 2.5% of Target value

Lower limit = Target value – 2.5% of Target value

3.3 Revision of Energy Conservation Guidelines

The Energy Conservation Guidelines applicable for Category-A industries will be revised time to time on a periodical basis based on inputs from various stakeholders and as per recommendations of the technical committee constituted by the Bureau of Energy Efficiency.

4.0 Energy conservation guidelines

The Energy Conservation Guidelines is a comprehensive hand holding document related to major energy consuming utilities in Category-A industries to guide top management as well as operators in industries to manage energy efficiently. The Guidelines shall provide guidance to prepare its own "Energy Management Manual" (EM Manual) for efficient operation of various energy consuming utilities in individual industry under Category-A.

4.1 Standards and targets

The Guidelines consist of two distinct components viz. (1) Standard component and (2) Target component for various common energy consuming utilities employed across industries covered under Category-A. For efficient operations of the industry, it is essential to operate various energy consuming utilities efficiently and ensure proper monitoring and recording of all key operating parameters pertaining to each utility.

An industry shall maintain optimum operating parameters of different utilities based on feedback received from relevant process sections, thereby achieving optimum operation of the utility, which shall be termed as "standard values" of operation. Thus, the standard values of a utility shall be defined as follows.

> ***Standards*** *are optimum performance values achieved by an energy consuming utility in daily operation.*

The industry shall further improve the performance of the utilities by operating them at best possible operating parameters, which shall be terms as "target values" of operation. The target values as mentioned in Guidelines are better than standard values, which the industry shall strive to achieve best possible performance of the utilities. Thus, the target values of a utility shall be defined as follows.

> ***Targets*** *are equal to the best achievable values of an energy consuming utility in daily operation.*

4.2 Components of standards

The standard component comprises four distinct sections that focus on relevant instructions concerning routine operations of respective utilities. These sections include (1) Management and control, (2) Measurement and recording, (3) Maintenance and inspection and (4) Installation of new facility. The primary focus of the standard components is provided in Table 4.1. The instructions are intended to guide the industries to achieve optimum performance of the utilities. The concrete activities in the Standard components (1), (2), (3) and (4) shall be described in the EM Manual.

Table 4.1: Components of standards

Component	Primary focus
1) Management and control	• This section provides guidelines for managing and controlling of key operating parameters in different energy consuming utilities in an industry e.g. air ratio, flue gas temperature, surface temperature, WHR, efficiency of motors, efficiency of fans, corrected power factor of electrical equipment, lighting power density etc. • It further covers load sharing during part load condition in a multi-utilities e.g. part load operations of equipment such as boiler, pump, fan, blower, air compressor, air-conditioning system etc.
2) Measurement and recording	• This section provides frequency of measurements and recording of operating parameters e.g. fuel consumption, temperature of steam, temperature of flue gases, analysis of flue gases, inlet and outlet temperatures of heating and cooling media, supply and return temperature of cooling water, etc.
3) Maintenance and inspection	• This section highlights preventive maintenance and overhauling schedule for various equipment.

	• It further provides schedule for regular calibration of instruments to maintain accuracy in data measurements.
4) Installation of new facility	• This section suggests directions for installation of energy efficient equipment for retrofitting in existing utility and system upgradation.

4.3 Components of targets

The target components provide a set of instructions for efficient use of energy consuming utilities or equipment and energy management practices that shall be followed to achieve best performance of the utilities. The instructions under target components shall relate to existing practices as well as include guidance for selecting new utilities with advanced features.

4.4 Scope of Energy Conservation Guidelines

The designated consumer (DC) generally follows energy management (EM) policies to reduce energy consumption in different energy consuming processes and utilities. The general guidelines for EM policy are provided in section 5. The primary equipment/ utilities considered under DCs shall be grouped as provided in Table 4.2.

Table 4.2: Details of utilities under Category-A industries

Sr. No.	Name of section	Utilities covered
1.0	Combustion of fuel	Boiler, industrial furnace, thermic fluid heater
2.0	Heating, cooling and heat transfer 2.1 Heating equipment 2.2 Air-conditioning and hot water supply utilities	Boiler, steam system, condensate recovery system, industrial furnace, thermic fluid heater Heat transport utilities, air-conditioning utilities, hot water utilities, thermic fluid heater
3.0	Waste heat recovery and usage	Boiler, condensate recovery system, industrial furnace, gas turbine, gas engine, diesel engine, thermic fluid heater

Sr. No.	Name of section	Utilities covered
4.0	Conversion of heat to electricity 4.1 Power generation facilities 4.2 Cogeneration facilities	Boiler, steam turbine, gas turbine, gas engine, diesel engine
5.0	Prevention of energy loss due to heat radiation and electric resistance 5.1 Prevention of heat loss due to radiation and conduction 5.2 Prevention of electricity loss due to electric resistance	Boiler, steam system, condensate recovery system, industrial furnace, thermic fluid heater, electrical distribution system
6.0	Conversion of electricity to motive power, heat and light 6.1 Facilities using motors and heaters 6.2 Industrial pump and pumping system 6.3 Industrial air compressor and compressed air network system 6.4 Industrial fans and blowers 6.5 Industrial lighting system	Motor, industrial heater, pumping system, air compressor and compressed air system, fan and blower, industrial lighting
7.0	Industry Energy Management System	Overall plant energy management

5.0 Energy Management Policy

The designated consumer shall manage energy appropriately, depending on input energy characteristics within the plant or in a utility in line with existing EM policies. The DCs shall modify EM policies, as needed and in line with points from A to K (mentioned below). The DC shall suitably and effectively conserve energy through complying with various standards, as prescribed in the Energy Conservation Guidelines, concerning various energy consuming utilities associated with different processes used.

Standard components	A. The designated consumer (DC) shall develop and adopt EM policies including installation of new utilities or upgradation of the existing ones. B. The DC shall prepare a suitable Energy Policy Statement within EM policy. It shall revisit the Energy Policy Statement on a periodical basis, and shall modify, as required. C. The DC shall develop a management structure for effective planning and implementation of energy conservation measures. D. The DC shall involve necessary resources (human and finance) to achieve energy conservation. E. The DC shall designate a Certified Energy Manager to ensure implementation of energy conservation measures. F. The DC shall prepare a document covering instructions on energy conservation at plant level (hereafter called "Energy Management Manual"), including energy conservation targets by retrofitting/replacing existing inefficient equipment or installing new facilities, as required. G. The DC shall ensure compliance of Energy Management at plant level. It shall

	review implementation status of target energy conservation measures and provide directions for future improvements. H. The DC shall review EM manual periodically and its compliance, and modify based on feedback from plant personnel. I. The DC shall discuss the Energy Management with the employees and provide training to capacitate them. J. The DC shall ensure proper monitoring and maintain recording in suitable documentation for each utility that enable generation of status report of individual utility. K. The DC shall undertake calibration of all instruments used in monitoring and measurement on a regular basis to ensure data reliability.
Target components	A. The DC shall manage gate to gate energy consumption and implement energy conservation measures that are technically and economically viable to improve energy performance of the plant. B. The DC shall identify energy conservation measures with appropriate implementation strategies. C. The DC shall consider existing standards for energy management systems such as ISO 50001 to ensure synergy. D. The DC shall ensure efficient utilization of thermal energy generated from primary energy sources. E. The DC shall optimize recovery of heat available in either flue gases or surplus steam for use in suitable energy consuming utilities within the plant. F. The DC shall target to recover and re-use energy generated while burning or processing combustible waste to the maximum extent.

	G. The DC shall identify and implement energy conservation measures to improve the performance of electrical equipment and reduce overall electricity consumption. H. The DC shall utilize services of accredited energy auditing firms, Energy Service Companies (ESCOs), etc. to identify and implement potential energy conservation measures and achieve energy efficiency. I. The DC shall put in place suitable instrumentation and software tools for monitoring energy consumption and verification of energy savings. J. The DC shall manage the specific energy consumption (SEC) as per targets set under Perform, Achieve and Trade (PAT) mechanism by complying with various standards of energy consuming utilities as mentioned in the Energy Conservation Guidelines and implementing appropriate energy conservation measures. K. The DC if being a lessee, shall cooperate with lessor to promote energy efficiency activities jointly under cost sharing mechanism, so that appropriate and effective energy conservation measures can be implemented as per the clause in the lessee agreement. L. The DC shall put in efforts to facilitate other industries to implement energy conservation measures through information sharing and advisory support to promote national initiative on energy conservation.

6.0 Combustion of fuel

The energy sources used in industries include both thermal and electrical energy. Thermal energy is generated from combustion of different types of fuels such as coal, petcoke & biomass (solid fuels), furnace oil, diesel, naphtha & internally generated liquid fuels (liquid fuels) and natural gas, LPG, off-gases, fuel gas & internally generated gaseous fuels (gaseous fuels). The thermal energy is either directly used in processes for heating, melting, etc. or used for power generation. This section provides EC guidelines covering combustion of fuels in boilers, industrial furnaces and thermic fluid heaters (TFH) in a rational way.

Standards components	
1) Management & control	A. The industry shall maintain optimum and correct air ratio while burning fuel(s) in boilers, furnaces and TFHs (hereafter termed as combustion facilities). The fuel combustion process shall be managed and maintained in accordance with the instructions provided on air ratios, which shall be provided in the **EM Manual**. B. The industry shall maintain air ratio for boiler as specified in Table 6.1 as Standard Value and use Table 6.2 for industrial furnaces/ TFH as Standard Value. C. In cases wherein more than one combustion (of fuel) utilities are used, combustion load for each utility of the industry shall be manged and controlled to achieve highest possible efficiency. The efficiency herein refers to the ratio of heat gained by the material to total heat input to the combustion utility. D. The combustion utilities shall be suitably operated to achieve high level of combustion efficiency under specific operating conditions which shall be described in **EM Manual**. The specific operatating conditions shall be finalised

	based on various factors of fuels such as particle size of solid fuels, moisture content, viscosity of liquid fuels, calorific value, pressure of gaseous fuels. E. The combustion utilities shall be managed according to the instructions provided in operation manual related to draft, operating temperature and loading conditions for optimum performance, which shall be described in **EM Manual**.
2) Measurement & recording	A. All the key parameters of combustion utility shall be maintained and recorded regularly. The frequency of measurements shall be adhered to, which shall be explained in the **EM Manual**. The industry shall use the measured data for evaluating the performance of combustion utility. Some of the parameters that shall be measured and recorded include quantity of fuel fired, temperature of exhaust gases, residual oxygen (O_2) & carbon monoxide (CO) in flue gases and unburnt carbon for solid fuels in bottom ash and fly ash. B. The industry shall measure useful heat gain either steam generation in boilers or quantity of material processed in furnaces for assessing the performance.
3) Maintenance & inspection	A. The industry shall undertake periodical inspection and maintenance of combustion facilities to maintain good operating conditions which shall be described in the **EM Manual**.
4) Necessary measures when installing new facilities	A. The industry shall decide the compatible size and system specifications of the combustion utility based on application, fuel type, temperature of combustion air and heat load fluctuations. B. The industry shall select suitable and appropriate combustion equipment along with accessories (e.g. burner, associated

	auxiliaries including built-in automation) for new utility. C. The industry shall select appropriate accessories for combustion air supply and integrate with combustion utility for automatic regulation of air flow considering real-time plant load and other operating conditions.
Target components	
	A. The industry shall make consistent and regular efforts to reduce air ratio of combustion facilities towards the reference air ratio as listed in Table 6.1 for boilers and Table 6.2 for industrial furnaces as target values. B. The industry shall retrofit suitable automatic air-fuel ratio control systems in each combustion utility, and integrate with control loop system, if not already installed, which shall be described in the **EM Manual**. C. The industry shall select and use appropriate combustion equipment (e.g. burners, auxiliaries), based on the type of combustion utility and the type of fuel used. The combustion system shall be capable of regulating fuel supply automatically in line with load fluctuations. D. The industry shall suitably modify air train to regulate combustion air flow and furnace pressure automatically. E. The industry shall consider regenerative burner while installing a new burner or replacing an existing one to recover and re-use heat from waste hot gases. F. The industry shall consider computer-aided automatic combustion management system/tool for finer control of combustion utility. G. The management shall install suitable on-line measurement and recording equipment

	to monitor and control key operating parameters in the combustion utility. The measurements shall include fuel supply, temperature of exhaust gases, residual oxygen and carbon monoxide levels in flue gases. H. The industry shall periodically collect and analyse unburnt carbon in fly ash and bottom ash for solid fuels.

Table 6.1: Air ratios for boilers[+]

Parameter	Boiler capacity (tph)	Load factor (%)	Air Ratio[@]				
				Coal^	Biomass fuel[#]	Liquid fuel	Gas fuel[&]
			Fixed bed[$]	Fluidized bed*			
Standard[α]	> 100	50 – 100	1.26-1.33	1.30-1.33	1.25-1.30	-	1.13-1.18
	51 - 100	50 – 100	1.33-1.40	1.35-1.42	1.31-1.38	-	-
	11 - 50	50 – 100	1.51-1.59	1.36-1.43	1.47-1.55	1.19-1.25	-
	Upto 10	50 – 100	1.54-1.62	1.40-1.48	1.49-1.56	1.26-1.33	1.19-1.25
Target[β]	> 100	50 – 100	1.14-1.22	1.18-1.21	1.20-1.25	-	1.08-1.13
	51 - 100	50 – 100	1.17-1.23	1.22-1.28	1.21-1.28	-	-
	11 - 50	50 – 100	1.31-1.38	1.22-1.28	1.32-1.39	1.13-1.19	-
	Upto 10	50 – 100	1.31-1.38	1.25-1.32	1.32-1.39	1.18-1.24	1.14-1.20

Source: Boiler performance data from different industries

\+ Combustion of fuels under Standard Temperature and Pressure (STP) conditions is assumed and effect of parameters such as variation in fuel compositions is ignored

@ Air Ratio is defined as the ratio of "actual air supplied" (AAS) to theoretical air requirement. Following formula shall be used for calculating air ratio (value rounded to two digits). The air ratio is considered based on steady state operation at constant load conditions and can be measured and verified at specific measurement points

$$\text{Air ratio} = \frac{21}{21 - \%\ \text{oxygen in flue gases}}$$

$ Includes combustion of coal other than fluidized bed

^ Fuels such as petcoke as used in industries such as cement are not included in the EC Guidelines

* Includes (1) Atmospheric Fluidised Bed, (2) Pressurized Fluidised Bed and (3) Circulating Fluidized Bed

Includes use of wood upto 10 tph capacities; bagasse or rice husk firing for other capacities.

& Gaseous fuel covers natural gas (NG) only. Fuels such as by-product gases as produced and used in steel industries are not considered.

α Standards are optimum performance values achieved by an energy consuming utility in daily operation.

β Targets are equal to the best achievable values of an energy consuming utility in daily operation

Note 1: Gross calorific value (GCV) of fuels

The GCV of different fuels, considering standard composition of fuels are given below.

- Indian coal - 3300 to 3700 kcal per kg; Liquid fuels (light diesel oil, high speed diesel and furnace oil) - 10,500 to 10,800 kcal per kg; Biomass fuels - 3100 to 4500 kcal per kg (source: https:// beeindia.gov.in/sites/ default/files/2Ch1.pdf)
- Bagasse - 2250 kcal per kg (http://biomasspower.gov.in/document/ regulatory-oreder/TN)
- Natural Gas (NG) : 8,500 – 9,000 kcal per Standard cubic meter (Source: GAIL India Limited)

Note 2: Load factor of boiler

- Load factor of boiler used for power generation shall be considered same as that of connected turbine load factor

Table 6.2: Air ratio for continuous type industrial furnaces+

Parameter	Kiln type	Air ratio@		
		Liquid fuel	Gas fuel&	Fuel gas#
Standard	Oil heating (TFH)	1.25-1.35	1.20-1.25	-
	Reheating furnace	1.25-1.35	1.20-1.25	-
	Process fired heater (Refinery)	-	-	1.14-1.31
Target	Oil heating (TFH)	1.20-1.25	1.15-1.20	-
	Reheating furnace	1.15-1.25	1.15-1.20	-
	Process fired heater (Refinery)	-	-	1.11-1.24

Source: Performance data from different industries; Centre for High Technology

+ Combustion of fuels under Standard Temperature and Pressure (STP) conditions is assumed and effect of parameters such as variation in fuel compositions is ignored

@ Air Ratio is defined as the ratio of "actual air supplied" (AAS) to theoretical air requirement. Following formula shall be used for calculating air ratio (value rounded to two digits). The air ratio is considered based on steady state operation at constant load conditions and can be measured and verified at specific measurement points.

& Gaseous fuel covers natural gas (NG) only. Fuels such as by-product gases as produced and used in steel industries are not considered.

Mix of fuel gases or off-gases with furnace oil or natural gas as per requirements

$$\text{Air ratio} = \frac{21}{21 - \%\ \text{oxygen in flue gases}}$$

Note 1: Gross calorific value (GCV) of fuels

The GCV of different fuels, considering standard composition of fuels are given below.

- Liquid fuels (light diesel oil, high speed diesel and furnace oil) - 10,500 to 10,800 kcal per kg; Biomass fuels - 3100 to 4500 kcal per kg (source: https:// beeindia.gov.in/sites/ default/files/2Ch1.pdf)
- Natural Gas (NG) : 8,500 – 9,000 kcal per Standard cubic metre (Source: GAIL India Limited)

7.0 Heating, cooling and heat transfer

The industry may need heating and/or cooling based on process requirements. The heat load is met through either direct heat transfer or indirectly through heat exchange media. The type of heat source would include steam/hot water from boiler, combustion products/flue gas in furnace, hot fluid from TFH, etc. The cooling demand in the industry is achieved with chiller (refrigeration) system and space comfort through heating, ventilation and air-conditioning (HVAC) system.

7.1 Heating equipment

Standards components	
1) Management & control	A. The utilities (boiler, furnace and thermic fluid heater) shall have capacities appropriate for desired performance. The facilities that use different sources of heat media such as steam, hot water, hot air, etc. (e.g. heating facilities, cooling facilities, dryers, heat exchangers, etc.) shall follow the instructions, which shall be described in the EM Manual. The instructions are related to temperature, pressure, volume, etc. to automatically control and optimize supply of heat quantity. B. Industrial furnaces used for heating, melting and heat treatment shall be operated to improve heat pattern in a way that increases thermal efficiency of the equipment which shall be elaborated in the EM Manual. C. The DC shall ensure optimum loading for better utilization of the capacity without over-loading or under-loading. D. In case of operation of multiple utilities in parallel for heating, etc., the load sharing for each utility shall be regulated/ adjusted in such a way that highest level of thermal efficiency may be achieved as a whole, which shall be described in the EM Manual.

	E. The DC shall optimize sequencing of material flow to reduce delays and avoid repeated heating of materials. F. Utilities for intermittent or batch operations shall be scheduled in a way that streamlines the entire chain of operation, which shall be described in the EM Manual. G. The DC shall maintain appropriate quality of feedwater according to IBR-1950 (Indian Boiler Regulation) or an equivalent standard as suggested by the manufacturers which shall be provided in the EM Manual. H. The DC shall close steam flow to the process that is not in operation. I. The DC shall use dry steam in heating processes to enhance heat transfer.
2) Measurement & recording	A. The DC shall measure and record operating parameters either on-line or periodically to enhance heat transfer which shall be described in the EM Manual. The operating parameters include temperature of heated or cooled objects, pressure, and flow rates.
3) Maintenance & inspection	A. Components related to heat transfer of the equipment, such as heat-transfer surfaces of boilers, industrial furnaces, heat exchangers, etc. shall be maintained according to the instructions concerning their maintenance and inspection, which shall be described in the EM Manual. The utilities shall be periodically cleaned to get rid of soot, scale or dirt to avoid deterioration of heat transfer surfaces and heat transfer performance.
4) Necessary measures when installing new facilities	A. While installing a new utility for heating, following points shall be considered. a) Use materials with highest possible thermal conductivity b) Adopt best possible layout of heat exchangers to improve total efficiency.

Target components	
	A. The DC shall use higher dryness fraction of steam for better heat transfer. It shall also install appropriate steam separator or steam trap to maintain the required dryness fraction of steam. B. The DC shall consider using improved properties and shapes of wall surfaces of industrial furnaces to enhance radiation heat transfer. C. The DC shall consider using improved properties and shapes of heat transfer surfaces to enhance heat transfer coefficient of such surfaces. D. The DC shall use higher thermal conductivity materials for heat exchanging components employed. E. The DC, wherever feasible, shall use direct heating of objects. F. The DC shall consider increasing the number of stages of evaporators in multiple effect evaporators based on the potential for enhancing overall thermal efficiency. G. The DC shall consider improving efficiency of distillation towers by optimizing parameters such as pressure, reflux ratio, vapour recompression, etc. H. The DC shall optimize the number of stages of heat exchangers and their layout for enhancing the thermal efficiency. I. The DC shall explore possibilities of integrating industrial furnaces operated at high temperatures and low temperatures to promote multi-step use of heat for improving overall efficiency of furnace systems. J. The DC shall use automatic control systems to ensure effective use of heat energy. K. The DC shall streamline processes that would require repeated heating. L. The DC shall consider including preliminary treatment methods that would help in energy saving. For example, preparatory steps such as removal of moisture content, preheating, and

	pre-grinding. M. The DC shall install boiler or industrial furnace with highest efficiency that meets the process requirements. N. Heating with vacuum steam media shall be considered as an alternative to hot water media used in heating facilities.

7.2 Air-conditioning facilities and hot water supply facilities

Standards components	
1) Management & control	A. The DC shall adopt section-wise air-conditioning system for operating parameters with signficant variations. For example, air conditioning requirement and load will be different for different sections of manufacturing, storage of products (finished or semi-finished) and workplace environment. Details of instrutions shall be described in EM Manual. These shall include parameters such as operational time, set temperature range (lower limit and upper limit), ventillation air per hour, and humidity. B. The DC shall manage air conditioning of office buildings to essential zones, reducing loads with potential options such as window shades, wall with low thermal mass, etc. and operate according to the instructions, which shall be described in EM Manual. The operating instructions shall include operational time, room temperatures, air ventillation per hour, humidity, and effective use of outdoor air. The utility shall adhere to air cooling and/or heating temperatures as recommeded in Energy Conservation Building Code (ECBC). C. The air conditioning system that include heat source utilities, heat transport utilities, and air conditioner utilities shall be controlled in a synchroized manner to improve overall energy efficiency, which shall be described in the EM

	Manual. The DC shall attempt to improve by modifying operational parameters without compromising the system performance. Some of the key operational parameters like cooling water temperatures, chilled/hot water temperatures and pressure based on seasonal variations in outdoor air conditions shall be considered. D. Air conditioning utilities with one or more heat sources using either similar or different energy sources shall be operated in a manner to achieve improvement in overall energy efficiency of the air conditioning system. The EM Manual shall elaborate on better operating practices for such arrangements. Overall improvement shall be established by opting optimum number of heat source utilities in service considering variations in out-door air conditions and heat load fluctuations. E. If the heat transport utilities includes more than one pump, the utility shall be managed to achieve improvement in energy efficiency and shall be described in the EM Manual. The DC shall use options such as auto controls to switch off pumps or change (increase or decrease) speed according to the load variations by integrating with variable frequency drives (VFD). F. In an air conditioner utilities, having more than one air conditioning equipment of the same model or more than one air conditioner of different types, the utility shall be managed in such a way that it achieves improvement in overall energy efficiency of the air conditioner utility, which shall be described in the EM Manual. G. Efficiency of hot water supply utilities shall be enhanced by reducing supply points with seasonal changes and load requirement in processes as described in the EM Manual. The instructions in EM Manual shall focus on output parameters such as temperature and pressure. H. Heat source utilities and associated auxiliary equipment (e.g. burner and water pump) shall be

	operated, monitored and automatically controlled in response to load fluctuations, which shall be described in the EM Manual. I. If multipe heat source equipment are provided in heat source utility for hot water supply system, the utility shall be managed in such a way that it improves overall energy efficiency of the heat source utilities, which shall be described in the EM Manual. The improvement shall be achieved through adjusting (increasing or decreasing) the numbers of units in operation based on the process load conditions.
2) Measurement & recording	A. The DC shall monitor and record parameters (e.g. temperature, and humidity) to keep track of air-conditioning in different sections of the industry. The DC shall use online monitors or hand-hold instruments for this purpose, which shall be described in the EM Manual. B. Parameters necessary to improve efficiency of overall HVAC system (that include heat source utilities, heat transportation utilities and air conditioner utilities) shall be periodically measured and/or recorded which shall be described in the EM Manual. C. Parameters necessary to improve the efficiency of hot water supply shall be measured and recorded periodically (e.g. quantity, feed water temperature and hot water supply temperature), which shall be described in the EM Manual.
3) Maintenance & inspection	A. The DC shall undertake periodical inspection and maintenance of air-conditioning utilities to maintain good operating conditions which shall be described in the EM Manual. The improvement shall include both at equipment level and HVAC system level to achieve overall energy efficiency. B. The DC shall maintain and inspect periodically hot water supply utilities to keep them in good conditions according to the instructions provided on maintenance and inspection, which shall be described in the EM Manual.

	C. Automatic control systems or devices used in air conditioning and hot water supply utilities shall be maintained and inspected periodically in order to keep them in good conditions, which shall be described in the EM Manual.
4) Necessary measures when installing new facilities	A. Air-conditioning utilities While installing a new air conditioning utility, the DC shall ensure the following: (a) Select a suitable utility that is capable of responding to changes in heat demands. The DC shall consider installing a dedicated control system for each section of air conditioning to ensure better control. (b) The DC shall install high efficiency system within heat source utility (e.g. heat pumps) as well as heat transport utility of integrated air-conditioning system to accommodate fluctuating load demands. It shall be equipped with split control, flow control, storage system, etc. The heat transport system shall use variable pump head control for efficient operation. (c) The DC shall use variable air-volume and flow-rate systems with speed control to respond to load variations. (d) The DC shall introduce suitable heat exchanger for reducing air cooling/ heating loads. For example, the DC shall consider options such as outdoor air cooling during winter season and water humidification to reduce air cooling loads. (e) The DC shall avoid direct discharge of exhaust heat from production systems close to air-conditioning section to avoid increase in air-conditioning loads. (f) The DC shall minimize air-conditioning loads by installing local air-conditioning system around workers or radiant heating in case the air conditioning of the entire workplace is not essential.

	(g) The DC shall avoid ingression of hot air or exgression of conditioned air by closing gaps and openings as much as possible to reduce air conditioning load. (h) The location and process of installing an outdoor unit of an air conditioner should be determined based on both solar radiation and ventilation condition of the installation location, in case the units are installed closely together, which shall be described in EM Manual. (i) The air conditioning utility shall be equipped with suitable control and measurement devices to manage operation on its own. The controlling parameters include temperature and humidity of different sections of air-conditioning. B. Hot water supply utilities The DC shall evaluate load assessment of hot water requirements to select suitable hot water supply utility to achieve overall energy efficiency. It shall consider following before undertaking installation of a new utility. (a) Select compatible technology that responds efficiently to load variations. (b) Install dedicated hot water supply system to cater to sections with lower loads. (c) Explore use of "heat pump system" and/or a latent heat recovery system for heat source utilities.
Target components	
	A. Air conditioning utilities The DC shall focus on the following aspects to ensure efficient use of energy in air-conditioning utility. (a) For only air conditioning, the DC shall use heat source equipment with high energy efficiency such as heat pump and storage system and gas cooling or heating system.

	For simultaneous air cooling and heating loads within the plant, the DC shall consider use of heat recovery system. Further, in case of availability of potential exhaust heat, use of a heat recovery system e.g. heat pump and exhaust-heat-driven heat source equipment shall also be considered. (b) The DC shall improve thermal insulation of walls and roofs for the air-conditioned areas. It shall include higher thickness of walls and roofs, low thermal conductivity materials, double-layer thermal insulation. It shall further consider reducing external heat sources through shielding solar radiation through windows using window shades, heat reflecting glasses, heat shield window films and thermal buffer zone with double insulation structure. (c) The air-conditioning utility shall be equipped with carbon dioxide sensor or similar type of device to minimize outdoor air handling load. It shall consider cooling of air with water from cooling tower during winter season. (d) The air-conditioning utility shall minimize air flow volume and circulation water volume by setting large temperature difference in the utility. (e) The DC shall insulate pipes and ducts to reduce heat losses. B. Hot water supply utilities The DC shall examine the following to enhance energy efficiency in hot water supply system. (a) Use heat pump or latent heat recovery system to enhance efficiency of hot water supply utilities (b) Use alternate systems to reduce power consumption in ventilation system in workplace, machine rooms and electric rooms. For example air volume controller with suitable sensors

8.0 Waste heat recovery and usage

Waste heat recovery (WHR) system is employed to recover and reuse sensible heat available in hot streams such as exhaust gases from boilers, furnaces, gas turbines, diesel generator (DG) sets, etc. WHRs are used in various applications depending on quantum of recoverable heat available for extraction. Some of the applications include WHR boiler, air pre-heater, charge/scrap pre-heating, economiser, etc.

Standards components	
1) Management & control	A. Recovery and reuse of waste heat from flue gases for different types of utilities (gas turbine, gas engine, diesel engine, boiler, industrial furnace, TFH, etc.) shall be managed according to the instructions concerning waste gas temperatures or waste heat recovery rates as described in the EM Manual. B. Recovery and reuse of waste heat in condensate return shall be managed according to the instructions concerning parameters such as quantity of condensate, temperature, etc. as described in the EM Manual. C. Recovery of sensible heat, latent heat, etc. as available from various sources (gas turbine, gas engine, diesel engine, boiler, industrial furnace, TFH, etc.) shall be managed according to the instructions concerning rate of recovery as described in the EM Manual. D. Waste heat from exhaust gases shall be utilized suitably according to temperature conditions (e.g. preheating temperature) and operating conditions of utilities.
2) Measurement & recording	A. The parameters concerning waste heat and its utilization in each utility shall be measured and recorded. These include temperature of waste heat, quantity of waste heat medium and composition, etc. which shall be monitored periodically and the data shall be recorded according to the instructions described in the EM Manual.

3) Maintenance & inspection	A. Systems such as heat exchangers and waste heat boilers (hereafter, "WHR utilities") shall be periodically maintained and regularly inspected according to the instructions mentioned in the EM Manual.
4) Necessary measures when installing new facilities	A. The DC shall employ adequate measures while installing a new pipe or system towards transportation of waste heat with minimum temperature drop. These measures include preventing air intrusion, enhancing thermal insulation, etc. B. The exhaust gas temperature of boiler shall be reduced by recovering sensible heat in flue gases by installing waste heat recovery equipment or retrofitting existing waste heat recovery system considering the reference values as specified in Table 8.1. C. The exhaust gas temperature of industrial furnace shall be reduced by recovering sensible heat in exhaust gases by installing waste heat recovery equipment or retrofitting existing waste heat recovery system considering the reference values as specified in Table 8.2. D. The DC shall undertake appropriate actions to maximize waste heat recovery while installing a new WHR utility. The actions shall include selection and use of materials with improved properties, shapes and areas of heat transfer (e.g. finned surfaces). E. The DC shall install on-line instrumentation to monitor temperature of exhaust gases and waste heat recovery media. F. The DC shall include suitable cleaning systems for WHR facilities to avoid scale formation and ensure optimum heat transfer as per instructions provided in EM Manual.

Target components	
	A. The DC shall put in efforts towards efficient heat recovery from various feasible waste heat sources (gas turbine, gas engine, diesel engine, TFH, etc.), taking into account type of fluid (e.g. contaminated fluid, corrosive fluid, etc.) so that the waste streams are exhausted at minimum possible temperatures. B. The exhaust gas temperature of boiler shall be reduced by recovering sensible heat in exhaust gases by appropriate measures and methods either on existing system or installing a new system considering the reference values as specified in Table 8.1. C. The exhaust gas temperature of industrial furnace shall be reduced by recovering sensible heat in exhaust gases using appropriate WHR either on existing system or installing a new system considering the reference values as specified in Table 8.2. D. The DC shall also consider other measures for improving overall waste heat recovery. These include appropriate sizing of duct or pipe, suitable layout, avoidance of leakage, use of efficient insulation materials, regular maintenance and use of temperature recording systems both at source and usage points. E. The DC shall enhance WHR system by considering use of materials with better properties, shapes (e.g. fins) and areas of heat transfer. The utility shall also install heat storage facilities. It shall further enhance recovery of waste heat through by considering new technology options such as Organic-Rankine Cycle (ORC), vapour absorption systems, etc.

Table 8.1: Flue gas temperature of boilers

Parameter	Boiler capacity (tph)	Flue gas temperature[@]				
		Coal		Biomass fuel[#]	Liquid fuel	Gas fuel[&]
		Fixed bed[$]	Fluidized bed*			
Standard[α]	> 100	140	140	140	-	130
	51 - 100	140	140	140	-	-
	11 - 50	210	140	180	190	-
	Upto 10	220	210	220	230	220
Target[β]	> 100	130	130	130	-	120
	51 - 100	130	130	130	-	-
	10 - 50	160	130	140	180	-
	Upto 10	190	180	180	180	180

Source: Boiler performance data from different plants

@ Average temperature at outlet of final stage of heat recovery from flue gas or chimney base

$ Includes combustion of coal other than fluidized bed

includes wood, briquette, rice husk, bagasse, etc.

* (1) Atmospheric Fluidised Bed, (2) Pressurised Fluidised Bed and (3) Circulating Fluidised Bed

+ Liquid fuels includes light diesel oil, high speed diesel and furnace oil

& Gaseous fuel covers natural gas (NG) only

Table 8.2: Waste heat recovery for industrial furnaces

Exhaust gas temperature (℃)	Standard[α] waste heat recovery rate (%)	Target[β] waste heat recovery rate (%)	Flue gas temperature[#] (℃)
Upto 600	30	38	250-300
600-1000	42	52	200-300
More than 1000	47	56	200-300

Source: Based on data from different industries

α Estimated heat drop based on upper limit of gas temperatures and net heat transfer with 60% efficiency for heat exchanger

β Estimated heat drop based on lower limit of gas temperatures and net heat transfer with 65% efficiency for heat exchanger

considering natural draft systems for higher flue gas temperature and induced draft system for lower temperatures

- The waste heat recovery rate is the ratio of heat recovered to the sensible heat available in exhaust gases under rated load operation
- Following formula shall be used for calculating waste heat recovery rate

$$\text{Waste heat recovery rate (\%)} = \frac{(\text{Exhaust gas temperature} - \text{Flue gas temperatue})}{\text{Exhaust gas temperature}} \text{ X } 100$$

where,

Temperatures measured in degree Celsius

9.0 Conversion of heat to electricity

Thermal power plants use solid, liquid and gaseous fuels for generation of electricity. The generated electricity can be supplied through grid or used for internal process requirements in industries. The type of power plants includes steam turbine, gas turbine, diesel engine, gas engine, etc.

9.1 Power generation utilities

Standards components	
1) Management & control	A. The thermal power plant which is used either for public distribution or dedicated captive power generation utility shall be operated efficiently, which shall be described in the **EM Manual**. Further, multiple power generation facilities operating in parallel shall be managed to ensure proper load distribution within the utilities and improve overall efficiency which shall be described in the **EM Manual.** B. The power generation plant shall take into consideration typical characteristics of each generation utility for determining load distribution while ensuring overall efficient operation.
2) Measurement & recording	A. The DC shall measure periodically the overall performance of the power generation and shall record the results according to the instructions, which shall be described in the **EM Manual**.
3) Maintenance & inspection	A. The DC shall be periodically inspected and maintained to ensure trouble free and smooth operation and achieve highest possible energy efficiency. Details of maintenance and inspection shall be described in the **EM Manual**.
4) Necessary measures when installing new facilities	A. The DC shall select and install a new power generation utility of optimum capacity taking into account existing power requirements and considering future trends of power demands

	for captive power generation. B. The design net heat rate of the newly installed power generating utility at the receiving end shall not be significantly higher than the average level of existing thermal power generation utilities.
Target components	
	A. The DC shall install state of the art on-line measurements and recording equipment to measure and control key operating parameters.

9.2 Cogeneration utilities

Standards components	
1) Management & control	A. The DC shall manage and operate equipment used in cogenertaion facilities (e.g. boilers, gas turbines, steam turbines, gas engines, and diesel engines) to achieve optimum energy efficiency under variable load conditions, which shall be described in the EM Manual. B. The DC shall take into account characteritics of different facilities to determine optimum load distribution to respond to load variations for achieving highest energy efficiency. C. For cogeneration utilities having back pressure or extraction type turbines, the industry shall control minimum allowable values of back pressure or bleeder pressure according to the instructions concerning the values, which shall be described in the EM Manual.
2) Measurement & recording	A. The key parameters that influence overall efficiency of equipment (e.g. boilers, gas turbines, steam turbines, gas engines, and diesel engines) shall be periodically measured and recorded according to the instructions concerning measurements and records of such parameters, which shall be described in the EM Manual. B. In case of cogeneration utilities operated under

		low pressure which is close to the minimum allowable limit for back pressure or extraction turbine, the facilities shall measure and record periodically the management parameters, which shall be described in the EM Manual. These key parameters which shall be measured and recorded include operational time, inlet/outlet pressure, back or extraction pressure, and quantity of steam used, etc.
3) Maintenance & inspection	A.	Cogeneration utilities shall be periodically maintained and inspected in a way that maintains the highest level of overall efficiency, which shall be described in the EM Manual.
4) Necessary measures when installing new facilities	A.	The DC shall thoroughly analyze the actual use and future trends of heat and power demands and availability of exhaust heat while selecting and installing a new cogeneration utility of optimum capacity. Historical data recorded for a period of one year or more shall be used for this purpose.
Target components		
	A. B.	The DC shall consider installing new cogeneration utility in case of large quantity of steam/ hot water demand and continuous availability of exhaust heat throughout the year. The DC shall explore modifying existing operating conditions of extraction/ back pressure turbine if it helps in improving overall performance of the utility while ensuring the services.

10.0 Prevention of energy loss due to heat radiation and electric resistance

Thermal energy and electrical energy are commonly used in various industrial processes. Radiation loss takes place in high temperature zones which is controlled by better insulation on the surface and reducing openings. Electrical losses occur in various distribution lines connecting electrical utilities such as resistance heating systems, cables, transformers, motors, etc.

10.1 Prevention of heat loss due to radiation and conduction

Standards components	
1) Management & control	A. The DC shall undertake thermal insulation work on different systems like steam and condensate pipes, ducts, equipment, etc. which are used for transporting heat media, process fluid for heating, etc. (hereafter, "heat-using utilities") according to industrial standard practices for thermal insulation works and equivalent standards. B. The existing industrial furnaces shall be thermally insulated to improve insulation performance to maintain external surface temperature based on the standard value as listed in Table 10.1. The external surface temperature for boiler shall be maintained as per the Note (2) provided in Table 10.1. C. For an existing furnace with batch operation having inside temperature of more than 600°C, the utility shall be provided with insulation to maintain surface temperature as listed in Table 10.1 as Standard Value.
2) Measurement & recording	A. The DC shall periodically measure all key parameters of surfaces to keep track and reduce heat losses. These parameters include temperature of external surfaces of furnace, heated object temperature, mass of the object

	and waste gas temperature, etc. The results shall be analyzed, heat losses shall be quantified and heat balance shall be prepared, which shall be described in the EM Manual.
3) Maintenance & inspection	A. Heat-using utilities shall be periodically inspected to maintain proper insulation to reduce heat losses according to the instructions concerning maintenance and inspection of the measures (e.g. thermal insulation work), which shall be described in the EM Manual. B. Steam traps shall be periodically maintained and inspected to prevent steam leaks and clogging caused by malfunctioning of traps. The maintenance and inspection of the steam traps shall be detailed in the EM Manual.
4) Necessary measures when installing new facilities	A. While installing a new heat-using utility, actions to improve thermal insulation shall be undertaken. These include employing optimum thickness of insulation, selecting low thermal conductivity material, multi-layer insulation, etc. B. The DC shall minimize heat losses through radiation and air ingression by adopting suitable measures. These include minimum openings, proper sealing, double doors, air curtains, etc. C. The DC shall reduce heat radiation area by transporting heat media through streamlined pipe route. D. For a batch operated furnace with operating temperature more than 1000°C, the utility shall apply veneering on interior surfaces.
Target components	
	A. The DC shall examine potential measures such as low thermal mass furniture and better insulation for bodies, bases, fixtures and equipment used in handling of hot materials to minimize heat losses. It includes boilers, furnaces, steam system, condensate recovery system, etc. B. The industrial furnace shall be provided with optimum insulation using compatible material to

	reduce heat losses from the surfaces. The surface temperature of industrial furnace shall be maintained as specified in Table 10.1 as Target Value. C. For batch type furnaces operating with an internal temperature of more than 600°C, the utility shall consider insulation based on the temperatures listed in Table 10.1 as Target Value. D. The DC shall examine various measures to improved thermal insulation of heat-using facilities. These include thickness of insulation, selecting low thermal conductivity insulating materials, veneering on internal surfaces, etc. E. The DC shall minimize heat losses through dissipation and air leakage by adopting appropriate measures. These measures include reduced openings, improved sealing, double doors, air curtains, etc. F. The DC shall examine existing thermal sealing and undertake measures in heat-using facilities to prevent leakage of heat media from locations like rotating parts, joints, etc. G. The DC shall also examine use of improved streamlined pipe route for transporting heat media to reduce heat radiations. H. The DC shall examine methods such as covering of open type facilities, steam-using facilities and transport facilities which use high-temperature materials to reduce heat losses, except in cases wherein it is required to cool the facilities while transportation.

Table 10.1: Surface temperatures of industrial furnace

Parameter	Furnace design temperature (℃)	Surface temperature (℃)#		
		Ceiling	Side wall	Bottom*
Standard	Upto 600	110	100	120
	600-1000	140	100	150
	More than 1000	180	120	200
Target	Upto 600	90	80	100
	600-1000	120	90	130
	More than 1000	150	110	180

Source: Based on data from different industries

\# indicates average skin temperature under steady state operation

* indicates bottom surfaces not in contact with ground but with open air

Note 1: The surface temperatures of rotary kilns in cement industries are generally observed to be higher than the range provided in the table, which are not included separately in the guidelines.

Note 2: The surface temperatures of boiler shall be maintained at about 15 to 20 ^{o}C above ambient temperature.

10.2 Prevention of electricity loss due to electric resistance

Standards components	
1) Management & control	A. The DC shall manage and operate electrical systems such as transformers and uninterruptible power supply systems to achieve highest efficiency and minimise energy losses, which shall be described in the EM Manual. It shall ensure efficient operation even during part load conditions. The DC shall further adjust the number of units (transformers or uninterruptible power supply systems) in operation for optimum load allocation as per power requirements of various sections. B. The DC shall undertake actions to reduce distribution losses in power receiving and transforming utilities . These actions shall include shorter distribution lines, proper-

	current carrying capacity of conductors and appropriate distribution voltage, etc. which shall be described in the EM Manual. C. Operating practices to control starting or stopping of capacitors in line with the operation of the utilities in which they are installed, shall be described in the EM Manual. D. The DC shall distribute single phase loads in such a way that there is no current imbalance in three-phase distribution system, which shall be described in EM Manual. E. The utility shall be equipped with phase-protection relay/ single phasing preventer to avoid burn out of motors. F. The utilities that use electricity (hereafter, "electricity-using utility") shall be managed and controlled according to the instructions concerning standard operating practices of the utility, which shall be described in the EM Manual. G. The DC shall manage and control current flow to electricity-using facilities to minimise electrical losses which shall be described in the EM Manual.
2) Measurement & recording	A. The DC shall periodically measure and record parameters that are required to reduce electricity losses, which shall be described in the EM Manual. Some of the parameters shall include electricity consumption and voltage, current and power factor in power receiving and transforming utilities etc.
3) Maintenance & inspection	A. The DC shall undertake preventive maintenance and routine inspection of electrical utilities (power receiving and transforming utilities and power distribution utilities), which shall be described in the EM Manual.
4) Necessary measures when	A. While installing a new power receiving and transforming utility or power distribution

installing new facilities	utility, the industry shall record existing power demand and assess future trends, which shall be used for deciding utility level distribution system and capacity. B. While installing new equipment for power receiving and transforming utilities, the DC shall select suitable capacity, high efficient equipment to achieve overall energy efficiency.
Target components	
	A. The DC shall examine the improvements of power factor at the receiving end by installing measures like automatic power factor controller, capacitor banks, etc. in the distribution facilities as shown as Target value in Table 10.2. B. The DC shall install advanced management systems such as Supervisory Control and Data Acquisition (SCADA), which shall be integrated with each of the electricity-using utility towards automatic monitoring and recording of all key operating parameters.

Table 10.2: Target power factor

Load type	Target power factor
Induction motor[#]	0.95
Distribution system	0.99
Induction furnace*	0.95
Welding machine	0.90 and above
DC drives	0.90 and above
Fluorescent lamp	0.95 and above

Source: Improving motor and drive system performance- A Sourcebook for industry

[#] PF is measured after correction system

* Capacitors usually included with induction furnaces

11.0 Conversion of electricity to motive power, heat and light

Electric motors are widely used in industries for various loads such as fans, blowers, pumps, compressors, conveyors, etc. A wide range of capacities of motors are used for these applications. Further, electricity is used for heating and melting applications in furnaces and various types of industrial lighting.

11.1 Facilities using motors and heaters

Standards components	
1) Management & control	A. The DC shall stop motor driven utilities when not in use or during idle operation, which shall be described in the EM Manual. It shall consider the relationship of losses with the electricity consumption at the start and power consumption during idle operation for the purpose. B. Parallel operation of multiple motors shall be managed in a way to achieve high efficiency of the motors as a whole, which shall be described in the EM Manual. Suitable load allocation during parallel operation of multiple motors shall be implemented during partial load conditions to maintain higher efficiency under varying load conditions. C. The DC shall review the current use, end pressure and discharge rate of fluid machines (e.g. pumps, fans, blowers, compressors, etc.) and manage to reduce the load of the connected electric motors according to the instructions which shall be described in the EM Manual. The instructions may include number of operating units, speed reduction, pipe layout and dimensions, impeller size, etc to cater to variable load conditions. D. The DC shall adopt measures in electric heating utilities (e.g. induction furnaces, arc furnaces, and resistance furnaces) to enhance efficiency,

	which shall be provided in the EM Manual. The measures inbclude loading pattern, reducing idle operation, better insulation, installation of waste heat recovery system, etc., as applicable. E. The electrolytic facilities shall use electrodes of suitable size, shape and characteristics and shall be managed to attain high efficiency, which shall be described in the EM Manual. The instructions include distance between electrodes, concentration of electrolytes, and contact resistance of conductors. F. The DC shall manage use of electricity in different types of electricity-using utilities (e.g. motor driven utilities, electric heating utilities, etc.) with a view to reduce electrical losses (e.g. voltage or current losses), which shall be described in the EM Manual.
2) Measurement & recording	A. The DC shall measure such parameters of electricity-using utilities and record the results which are necessary to reduce electrical losses, which shall be described in the EM Manual.
3) Maintenance & inspection	A. The motor-driven utilities shall be periodically inspected and maintained to reduce mechanical losses occurring in electric motors, power transmission units, and machines that apply loads to the motors, which shall be described in the EM Manual. B. The motor-driven utility shall be periodically inspected and maintained for different fluid machines (e.g. pumps, fans, blowers, and compressors) to prevent leakages and reduce resistance of pipes and ducts, which shall be described in the EM Manual. C. The DC shall reduce electric resistance losses in electric heating utilities and electrolytic utilities through periodic maintenance and inspection of wire connections, contacts of switch, etc. which shall be described in the EM Manual.

4) Necessary measures when installing new facilities	A. The DC shall install and use efficient motors of suitable sizes as provided in Table 11.1. B. The DC shall install motors with compatible configurations to meet applications with large fluctuations of loads.
Target components	
	A. The DC shall install and use high energy efficient motors as provided in Table 11.1. B. The industry shall install energy saving measures such as Variable Frequency Drive (VFD) in a motor applied utility having large load fluctuations. C. The DC shall examine different heating methods (combustion of fuel, steam, hot air, thermic fluids, electric heating, etc.) for selection of electric heating. It shall consider parameters such as heat load, temperature range and energy costs for comparison.

Table 11.1: Energy efficiencies of IE3 motors

Rating (Kw)	Efficiency (%)		
	2-Pole	4-Pole	6-Pole
0.37	75.5	73.0	71.9
0.55	78.1	78.0	75.9
0.75	80.7	82.5	78.9
1.1	82.7	84.1	81.0
1.5	84.2	85.3	82.5
2.2	85.9	86.7	84.3
3.7	87.8	88.4	86.5
5.5	89.2	89.6	88.0
7.5	90.1	90.4	89.1
11	91.2	91.4	90.3
15	91.9	92.1	91.2
18.5	92.4	92.6	91.7
22	92.7	93.0	92.2
30	93.3	93.6	92.9
37	93.7	93.9	93.3
45	94.0	94.2	93.7
55	94.3	94.6	94.1

Rating (Kw)		Efficiency (%)	
	2-Pole	4-Pole	6-Pole
75	94.7	95.0	94.6
90	95.0	95.2	94.9
110	95.2	95.4	95.1
125	95.3	95.5	95.2
132	95.4	95.6	95.4
160	95.6	95.8	95.6
200	95.8	96.0	95.8
250	95.8	96.0	95.8
315	95.8	96.0	95.8

Source: IS 12615:2011 (Three-phase, 50Hz, single speed & squirrel cage induction motors)

Note: IE3 motors stand for Premium Efficiency level; However, HT and DC motors are excluded in the table.

11.2 Pumps and pumping system

Pumps are used for a wide range of applications to transfer fluids through mechanical action. According to basic operating principle, pumps can be classified either dynamic or positive displacement pump. Dynamic pumps are further classified into centrifugal pump and special effect pump. Positive displacement pumps are classified into rotary pump and reciprocating pump. Centrifugal pumps account for the major share of electricity consumption in industrial sector. Some of the centrifugal pumps used by the industry include (1) Mono-block pump, (2) End suction pump, (3) Split case pump and (4) Multi-stage pump etc. The guideline covers (i) Centrifugal pump, (ii) Boiler feed water pump (BFP) and (iii) Vertical turbine pump.

Standard components	
1) Management & control	A. The DC shall use "characteristic curves" provided by the manufacturer for monitoring and control of pump operation. The pump(s) shall be operated close to "Best Operating Point (BOP)" as specified by pump manufacturer. B. The DC shall use pumps with highest efficiency to meet the base load when multiple pumps

	are in operation. C. In case of the DC using multi-pumps, it shall manage and control loading of pump in such a way that it achieves highest possible loading near BOP in respective characteristic curve. D. The DC shall ensure optimum loading of pumps during entire range of operation both during full load or part load, while operating multiple pumps in parallel which shall be provided in EM Manual. E. The DC shall manage piping network of pumping system and control operating parameters such as flow rate, pressure and temperature, which shall be provided in EM Manual. F. The DC shall maintain minimum Net Positive Suction Head (NPSH) of pumps as prescribed by the manufacturer.
2) Measurement & recording	A. The DC shall measure and record key operating parameters such as total differential head, flow rate and power consumption to evaluate efficiency of pumps which shall be described in EM Manual. B. For centralised system using larger pumps, the DC shall integrate energy meters and flow meters for on-line monitoring and recording of data. Periodical measurements shall be undertaken for decentralized smaller capacity pumps.
3) Maintenance & inspection	A. The DC shall undertake routine/ scheduled overhauling of pumps according to the instructions provided by the manufacturers, which shall be described in EM Manual. B. The DC shall maintain and inspect parameters such as speed of motor, body temperature in pump ends and vibration on a periodical basis, which shall be described in EM Manual. C. The DC shall undertake corrective maintenance in case of significant drop in total

	differential head observed in pumping system. D. The DC shall ensure dynamic balancing of pump assembly after each overhauling.
4) Necessary measures when installing new facilities	A. The DC shall select correct capacity of pump with energy efficient systems such as IE3 motor or permanent magnet synchronous motor, variable frequency drives (VFD), cogged v-belts for belt driven systems, etc., while considering existing demand and immediate future expansion plans. B. The DC shall undertake water balance of the plant to assess total pumping capacity. C. The DC shall undertake dynamic balancing of pump assembly during installation. D. The DC shall select and install pump with highest possible efficiency while matching the plant requirements with pump performance at BOP. E. The DC shall retrofit existing pumping system with 'variable frequency drives' (VFDs) for fluctuating load conditions, which shall be described in EM Manual. F. The DC shall optimize number of stages available in multi-stage pump (e.g. boiler feedwater pump) in case of availability of head margins. G. The DC shall design and install pumping network with minimum system resistance using seamless pipes, which shall be described in EM Manual. H. The DC shall use booster for small loads requiring higher pressures.
Target components	
	A. The DC shall select and install most efficient pumps while matching BOP with system parameters, considering both existing requirements and immediate expansion plans. B. The DC shall install proper size of suction valve as recommended by the manufacturers.

	C. The DC shall further include measures such as correct sizing, seamless or fibre-reinforced plastic (FRP) pipe, better layout, plugging off leakages, application of improved insulation (hot and cold media), regular maintenance and installation of appropriate measurement systems for pressure and flow both at source and points of usage.

11.3 Air compressors and compressed air network

Air compressors are used in industries for a variety of applications to meet process requirements, operate pneumatic tools and meet instrumentation needs. These are mechanical devices use to compress and pressurize air. The centralised compressor air network consists of compressor (s), filter, after cooler, dryer, intelligent electronic control system, receiver tank (s), distribution piping, air cylinder, nozzle, ejector, etc. The pressurized air is transferred to various points of usage either directly or through receiver tanks. The compressors can be classified into (1) positive displacement compressor and (2) dynamic compressor.

Standard components	
1) Management & control	A. The DC shall ensure drawing of clean, cool and dry air by compressors for optimum performance. It shall manage and control operations as per the instructions provided in EM Manual in compressed air system. B. The DC shall use suitable size of air compressors to meet plant demands. C. The DC shall pre-set minimum possible generation pressure to optimise system performance, which shall be explained in EM Manual. D. The DC shall install receiver tanks with sufficient capacities for storing compressed air to cater to load demands and fluctuations. E. The DC shall use dedicated air compressor to meet exclusive high or low pressure demands. F. In case of operation of multiple air compressors, the DC shall use the most efficient compressors

	to meet base load.
2) Measurement & recording	A. The DC shall undertake on-line monitoring of pressure and air flow at the downstream of compressor and power consumption of individual compressor to assess the performance i.e. Specific Power Consumption (SPC) which shall be described in EM Manual.
3) Maintenance & inspection	A. The DC shall inspect and clean air filters on a weekly basis. The replacement of air filter shall be based on suction air conditions. B. The DC shall undertake overhauling of air compressor on a periodical basis as recommended by the manufacturer. C. The DC shall avoid moisture carryover by compressed air. It shall drain the moisture accumulated on a regular basis. D. The DC shall conduct leakage test and plug off compressed air leakages, which shall be described in EM Manual.
4) Necessary measures when installing new facilities	A. The DC shall undertake demand assessment of compressed air to select suitable compressed air system based on existing requirements as well as considering immediate expansion plans. This includes energy efficient systems such as in-built VFD, motor with permanent magnet, inverter type air compressor, etc. B. The DC shall select and install air compressor having lowest SPC while meeting the compressed air demands. C. The DC shall install air compressor in a direction that a hermetically closed room or intake of contaminated air (oil, gas, etc.) is avoided. D. The DC shall design and install compressed air network with minimum pressure drop. It shall use seamless metallic pipes or better quality fibre reinforced plastic (FRP) pipe for compressed air lines, which shall be described in EM Manual. E. The DC shall install intelligent electronic control system to minimise energy consumption and

	reduce loss of compressed air. It shall also include an auto drain system for moisture removal. F. The DC shall locate air compressors in such a way that it reduces piping length and minimises line pressure losses. G. The DC shall meet fluctuations in compressed air demands using VFD (variable frequency drive) enabled screw air compressors. In case of multiple air compressors system, the DC shall use one inverter type air compressor with suitable pressure setting to meet variable load conditions while other air compressors shall be used in continuous operation to cater to base load. H. The DC shall use centrifugal compressor for meeting high volume with low pressure applications, wherever feasible. I. The DC shall install air dryer in the distribution line which supplies to dry air usage points only e.g. instrumentation air. J. The DC shall ensure proper location of air compressor and quality of suction air as per the recommendation of the manufacturers, which shall be described in EM Manual.
Target components	
	A. The DC shall undertake demand assessment of compressed air at plant level to select and install suitable compressed air system B. The DC shall avoid installing oversized air compressor which may lead to inefficiencies. C. The DC shall undertake necessary measures such that the overall leakage from compressed air network shall remain less than 10% of total compressed air generation. D. The DC shall optimise compressed air system using ring-frame network and avoiding unnecessary bends, redundant pipes, valves, etc.

$$\text{Specific power consumption (SPC)} = \frac{\text{Actual power consumption (kW)}}{\text{Free air discharge } (Nm^3/minute)}$$

$$\text{Leakage rate (\%)} = \frac{\text{Onload time (sec)}}{\text{Onload time (sec) time+off load time (sec)}} \times 100$$

11.4 Fans and blowers

Industrial fan and blower systems are employed to generate low pressure air volumes of air or gases for transferring against the system resistance caused due to ducts, dampers or other components. Such systems are used for different applications to transfer air through mechanical action. Based on operating principle, fans are grouped in two categories namely (1) Centrifugal fans and (2) Axial flow fans. Similarly, industrial blowers are grouped into (1) Centrifugal blowers and (2) Positive displacement blowers. The selection of a fan or blower depends on various process requirements such as air volume, system resistance, output pressure and working environment.

Standard components	
1) Management & control	A. The DC shall use "Characteristic curves" provided by the manufacturer for managing and controlling operations of fans and blowers. It shall operate fan/blower close to "Best Operating Point" (BOP) of the characteristic curve, which is the intersection of fan curve and system resistance curve. B. In a DC having multiple fans, it shall use fans in series for high resistance, whereas adopt parallel connection for low resistance system. C. The DC shall operate more fans in parallel instead of a single large fan for higher volume requirements.
2) Measurement & recording	A. The DC shall measure and record key operating parameters such as pressure, temperature and power input when operated at stable conditions and rated speed to assess specific energy consumption

	(SEC), which shall be described in EM Manual. B. In case of centralised system using larger fans/ blowers, the utility shall integrate energy meters and flow meters for on-line monitoring and recording of operating parameters. C. For DC using smaller fan/ blower, it shall undertake periodical measurements of pressure head, air velocity and power consumption.
3) Maintenance & inspection	A. The DC shall undertake routine overhauling of fans and blowers according to the instructions provided by the manufacturers, which shall be described in EM Manual. It shall ensure dynamic balancing of fan/ blower assembly after each overhauling. B. The DC shall maintain and inspect parameters such as speed of motor and vibration on a periodical basis, which shall be described in EM Manual. C. The DC shall ensure allowable impeller inlet seal clearances that include axial overlap, radial clearance, back plate clearance and labyrinth seal clearance. It would further ensure "full open" and "full close" conditions of inlet damper positioning for efficient operation of fan/ blower. D. The DC shall conduct periodical inspection for leakages and plug off leakages in distribution lines, which shall be described in EM Manual. E. The DC shall undertake corrective maintenance in case of significant drop in pressure head observed in the system. F. The DC shall calibrate instruments used for monitoring of operating parameters to ensure accuracy of data.
4) Necessary measures when installing new	A. The DC shall select and install correct capacity of fan/blower considering existing

facilities	requirements, immediate expansion plans, plant layout and routing of pipes,. The system shall be equipped with built-in Variable Frequency Drive (VFD) system. . B. The DC shall ensure dynamic balancing of fan/ blower assembly while installation a new system. C. The DC shall select and install fan/blower having highest possible efficiency as provided in Table 11.2 while matching the plant requirements at BOP. D. The DC shall use booster for small loads requiring higher pressures. E. The DC shall undertake demand assessment of air to select suitable fan or blower as applicable while considering the dust type, its concentration, etc. while handling dust-laden gases. F. The DC shall select fan or blower with energy efficient systems such as IE3/ permanent magnet synchronous motor, variable frequency drives (VFD), etc. to maintain optimum performance. G. The DC shall install fans and blower in a direction that a hermetically closed room or intake of contaminated air (oil, gas, etc.) is avoided. H. The DC shall design and install fans and blowers network with minimum system resistance using seamless pipes, which shall be described in EM Manual. I. The DC shall replace over-sized fan/ blower with an optimum size system to meet process requirements for high-load conditions. J. The DC shall retrofit existing fan or blower with 'variable frequency drive' (VFD) in case of fluctuating load conditions, which shall be described in EM Manual. K. The DC shall manage piping network of the

	system and control operating parameters such as air flow, pressure, temperature, etc. to ensure minimum system resistance which shall be described in EM Manual. L. The DC shall install fan/ blower in proper location and ensure suitable quality of suction air as recommended by the manufacturers, which shall be described in EM Manual. M. The DC shall ensure proper belt alignment to minimize side wear and evenly distributed stress on the entire belt for belt driven system. N. The DC shall replace/ trim impeller blades as per requirements of the process for optimum loading.
Target components	
	A. The DC shall assess air volume demand of the plant to identify total system capacity. B. The DC shall select and install most efficient fans and blowers as shown in Table 11.2, while matching BOP and considering both existing requirements and immediate expansion plans. C. The DC shall ensure proper sizing of inlet of blower as per design values. D. The DC shall further include measures such as correct sizing of pipe, appropriate layout, plugging off leakages, application of improved insulation (for hot stream), regular maintenance, recording system, etc. E. The DC shall install multiple systems in parallel to generate higher volume in place of single large system.

Table 11.2: Efficiency of fans

Fan categories		Peak efficiency range (%)
Centrifugal fan	Airfoil backward curved/ inclined	79 – 83
	Modified radial	72 – 79
	Radial	69 – 75
	Pressure blower	58 – 68
	Forward curved	60 – 65
Axial fan	Van-axial	78 – 85
	Tube-axial	67 – 72
	Propeller	45 – 50

Source: Secondary data from websites

$$\text{Specific power consumption (kW/m}^3\text{/min)} = \frac{\text{Actual power consumption (kW)}}{\text{Total air volume } (m^3/minute)}$$

$$\text{Fan mechanical efficiency (\%)} = \frac{Volume\ \left(\frac{m^3}{hr}\right) X\ Total\ pressure\ (mm\ WC) X\ 100}{102\ X\ Power\ input\ to\ fan\ shaft\ (kW)}$$

$$\text{Fan static efficiency (\%)} = \frac{Volume\ \left(\frac{m^3}{hr}\right) X\ Static\ pressure\ (mm\ WC) X\ 100}{102\ X\ Power\ input\ to\ fan\ shaft\ (kW)}$$

11.5 Lighting system

Standards components	
1) Management & control	A. Lighting systems shall be managed according to the instructions based on Energy Conservation Building Code (ECBC) ensuring required lighting power density as mentioned in Table 11.3 and IS Code of Practice for Industrial Lighting: 6665-1972, or their equivalent standards, which shall be described in the EM Manual. Dimming or turning-off the light shall be managed in a way that eliminates excessive or unnecessary lighting, which shall be described in the EM Manual.
2) Measurement & recording	A. The DC shall periodically measure illumination level of lighting systems installed in various sections and shall be recorded according to the instructions concerning measurements and records of illuminance in different process sections or workplaces to be lit, which shall be

	described in the EM Manual.
3) Maintenance & inspection	A. Lighting systems shall be periodically maintained and inspected according to the instructions concerning maintenance and inspection, which shall be described in the EM Manual. The instructions shall include cleaning and replacement of lighting fixtures and lamps.
4) Necessary measures when installing new facilities	While installing a new lighting system, the DC shall optimize energy use in lighting, based on the information concerning lighting systems in the EC Building Code. A. The DC shall replace inefficient lighting with energy efficient lighting facilities such as LEDs, induction lamps, etc. maintaining standard illumination with minimum lighting power density (LPD). The LPD range for a few application areas in industries is shown in Table 11.3. B. The DC shall select suitable lighting fixtures that can be easily maintained and allow easy cleaning and replacement of light source. C. The DC shall provide due consideration to factors affecting total lighting efficiency while selecting lighting fixtures. The factors include illuminance efficiency of the light sources, efficiency of lighting circuits and lighting fixtures etc. D. The DC shall install systems that avail natural day light (e.g. use of translucent roofs) to maximise lighting and reduce electric lighting load. E. The DC shall install appropriate control systems to auto switch off or dimming of lighting system. It shall include measures like motion sensor, timers, and interlocking with security systems to avoid lighting when not required.
Target components	
	A. The DC shall use lighting fixture with a dimming function and automatic control devices, when natural lighting can be used. B. The DC shall consider using energy efficient lighting system such as LED and induction

	lighting along with suitable auto control systems to improve energy efficiency. C. The DC shall install natural lighting system e.g. translucent sheets, etc. to maximize energy saving. D. The DC shall use solar photo voltaic (SPV) based lighting system to use renewable energy sources.

Table 11.3: Lighting power density for industries

Lighting area	Average illumination (Lux)	Lighting power density (w/m^2)
Administrative building	50 - 400	5.0-9.5
Administrative corridor	100	2.3-7.1
Shop floor lighting (process)	150 - 300	6.0-12.0
Workshop	150 - 300	7.1-14.1
Warehouse - storage area	100 - 150	3.5-7.08

Source: Energy Conservation Building Code, Government of India

The lighting power density (LPD) is arrived by the following formulae.

$$LPD\ (\frac{W}{m2}) = \frac{Lux}{Efficacy}$$

$$Lux = \frac{lumen}{m2}$$

$$Efficacy = \frac{lumen}{watt}$$

12.0 Industry Energy Management System

Industry Energy Management Systems (IEMS) for a DC shall have standing instructions for the following actions to study efficient use of energy.

Component	Energy management system
Standard components	A. The dedicated certified energy manager will be responsible to monitor and control energy use pattern within the industry. B. The energy manager shall ensure periodic monitoring activities for all major energy consuming equipment or system. The schedule may be yearly, seasonal, monthly, weekly, daily, or hourly based on the type of requirements of the system or equipment. The results of performance of the systems shall be improved, if the performance is lower than the desired value. C. The DC shall review maintenance conditions and compare operating characteristics, performance deterioration, etc. to take remedial actions and improve energy efficiency.
Target components	A. The DC shall undertake appropriate actions to achieve energy efficiency in individual equipment as well as in industry as a whole. B. The DC shall implement integrated and centralized automatic controls for various facilities (e.g. combustion, heat-using, waste heat recovery, cogeneration, electricity-using, air conditioning, ventilating, and lighting facilities) to improve energy performance.