Energy Conservation
18EEO306T
Unit-1

ऊर्जा संरक्षण

Course Code	18EEO306T	Course Name	ENERGY CONSERVATION	Course Category	O	Open Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	Electrical and Electronics Engineering	Data Book / Codes/Standards	Nil		

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1 :	Outline the concepts of world energy scenario in industries
CLR-2 :	Describe the basics of electrical system
CLR-3 :	Impart knowledge on various methods of improving energy efficiency in industries
CLR-4 :	Give an overview about the energy policies, energy planning and policy making in India
CLR-5 :	Provide an understanding of the basics of energy conservation method and energy auditing in industries
CLR-6 :	Create overall structure of energy conservation starting from environmental aspects to energy management systems

		Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO – 3
CLO-1 :	Gain knowledge of world energy scenario	2	75	75	H	-	-	-	-	-	-	-	-	-	-	-	L	L	L
CLO-2 :	Understand the concepts of electrical system	3	75	75	H	-	-	-	-	-	-	-	-	-	-	-	M	M	M
CLO-3 :	Assess the energy efficiency in industrial system	3	75	75	H	-	-	-	-	-	H	H	-	-	-	-	M	H	M
CLO-4 :	Analyse the energy policies, energy planning and policy making in india	3	75	75	H	-	-	-	-	-	L	H	-	-	-	-	M	M	H
CLO-5 :	Correlate with various methods of energy conservation	3	75	75	H	-	-	-	-	-	L	H	M	M	-	-	M	H	M
CLO-6 :	Implement energy conservation methods and laws to save energy	3	75	75	H	-	-	-	-	-	M	H	M	M	-	-	M	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Energy classificatios	Introduction Electrical Systems	Air condition and refrigeration	Introduction to energy policy	Investment - need, appraisal and criteria
	SLO-2	Power Past & Present scenario of World	Electrical network types and classifications	Diesel Generator	National energy policy in the last plan periods	Financial analysis techniques
S-2	SLO-1	Sectorial energy consumption	HT supply	Energy Efficiency in Building	ISO-50001, PDCA, PAT scheme	Simple payback period
	SLO-2	domestic, industrial and other sectors	LT supply	Energy Efficiency in Building	BEE & State Development Agencies & EESL Programmes	Return on investment
S-3	SLO-1	energy needs of growing economy, energy intensity	Transformers and its operation	Savings opportunities in HVAC	Municipal & Agriculture DSM Initiatives	Net present value, internal rate of return, cash flows
	SLO-2	long term energy scenario, energy pricing	Types of transformer	Fans and blowers	Energy use and Energy supply	Net present value, internal rate of return, cash flows
S-4	SLO-1	energy security, energy conservation	Cables – and its construction	Conservation opportunities	Overview of renewable energy policy and the Five Year Plan programme	Risk and sensitivity analysis
	SLO-2	energy conservation importance, energy strategy for the future	Types and Cable Sizing	Pumps - CASE STUDY	Standards and Labelling Programme EEC initiatives in Other Sectors	Financing options
S-5	SLO-1	National Energy consumption Data	Concept of Capacitors	Control strategies	Basic concept of Input-Output analysis	Energy performance contracts and role of Energy Service Companies (ESCOs)
	SLO-2	Energy Pricing	Types of Capacitors	Conservation opportunities	Concept of energy multiplier and Implication of energy multiplier for analysis of regional and national energy policy Organizational structure	Energy Monitoring
S-6	SLO-1	Environmental aspects associated with energy utilization	Power Factor Improvemen	Cooling Tower -performance	key developments and changes in India's energy policies and planning in the context of energy efficiency and environmental concerns	Targeting: Defining monitoring & targeting

	SLO-2	*Environmental aspects associated with energy conservation*	*Harmonics*	*Efficient system operation*	*key developments and changes in India's energy policies and planning in the context of energy efficiency and environmental concerns*	*Targeting: Defining monitoring & targeting*
S-7	SLO-1	*Energy Auditing: Needs, Types,*	*Electric Motors – Motor Efficiency Computation*	*Efficient system operation*	*regulatory frameworks and reforms across various energy sectors*	*elements of monitoring & targeting*
	SLO-2	*Methodology and Barriers*	*Energy Efficient Motors*	*Validation of energy saving using application software*	*regulatory frameworks and reforms across various energy sectors*	*Data and information-analysis, techniques*
S-8	SLO-1	*Role of Energy Managers*	*Illumination – Lux, Lumens*	*Energy saving opportunities*	*Energy Policies success stories, failures*	*Energy consumption*
	SLO-2	*Needs of Energy Managers*	*Types of lighting, Efficacy*	*Energy saving opportunities*	*Energy saving potential of technology*	*Production, cumulative sum of differences (CUSUM).*
S-9	SLO-1	*Instruments for energy auditing*	*LED Lighting And types*	*Assessment of cooling towers*	*Energy tariffs and Energy Instrument*	*Energy Management Information Systems (EMIS)*
	SLO-2	*Energy conservation*	*Scope Of Encon In Illumination*	*Assessment of cooling towers*	*CASE STUDY for energy tariffs in industry*	*Energy Management Information Systems (EMIS)*

Learning Resources	1. *Witte. L.C., P.S. Schmidt, D.R. Brown, Industrial Energy Management and Utilisation, Hemisphere Publ, Washington, 1988* 2. *Callaghn, P.W. Design and Management for Energy Conservation, Pergamon Press, Oxford, 1981* 3. *Energy Manager Training Manual (4 Volumes) available at www.energymanager training.com, a website administered by Bureau of Energy Efficiency (BEE), a statutory body under Ministry of Power, Government of India, 2004*	4. *R Loulou, P R Shukla and A Kanudia, Energy and Environment Policies for a sustainable Future, Allied Publishers Ltd, New Delhi, 1997* 5. *Handbook on Energy Efficiency, TERI, New Delhi, 2001* 6. *https://www.edx.org/course/incorporating-renewable-energy-in-electricity-grids-2*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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THINK?

WHAT IS ENERGY?

SOURCES OF ENERGY

?

ENERGY CONSERVATION: WHY?

CONSERVATION OF ENERGY: HOW?

WHAT IS THE ALTERNATIVE?

Energy Classification

Energy is one of the major inputs for the economic development of any country. In the case of the developing countries, the energy sector assumes critical importance in view of the ever-increasing energy needs, requiring huge investments to meet them.

The consumption of energy is increasing at a fast pace while available resources remain limited. The global need for energy is increasing on an average by about 2.4% every year. Out of the total amount of primary energy, over 85% comes from fossil fuels. The current consumption of fossil fuels, particularly oil, is not sustainable in the long term.

Energy consumption also has a significant impact on our natural environment. There is clear evidence that climate change is caused by human activity, mostly related to the use of energy.

Energy, that we use, can be classified into several types based on the following criteria:

- Primary energy and secondary energy
- Commercial and non commercial energy
- Renewable and non-renewable energy

1.2 Primary and Secondary Energy

Primary energy refers to all types of energy extracted or captured directly from natural resources. Primary energy can be further divided into two distinctive groups:

- Renewable (solar, wind, geothermal, tidal, biomass, hydel etc.)
- Non-renewable (fossil fuels: crude oil and its products, coal, natural gas, nuclear, etc.)

The primary energy content of all fuels is generally expressed in terms of toe (tonne of oil equivalent) and is based the following conversion factor.

One tonne of oil equivalent (toe) = 1 x 10^7 kcal = 11630 kWh = 41868 MJ

Primary energy sources are mostly converted in industrial utilities into secondary energy sources; for example coal, oil or gas converted into steam and electricity. Primary energy can also be used directly. Some energy sources have non-energy uses, for example coal or natural gas can be used as a feedstock in fertiliser plants. Primary energy is transformed in energy conversion process to more convenient forms of energy such as electricity, steam etc. These forms of energy are called secondary

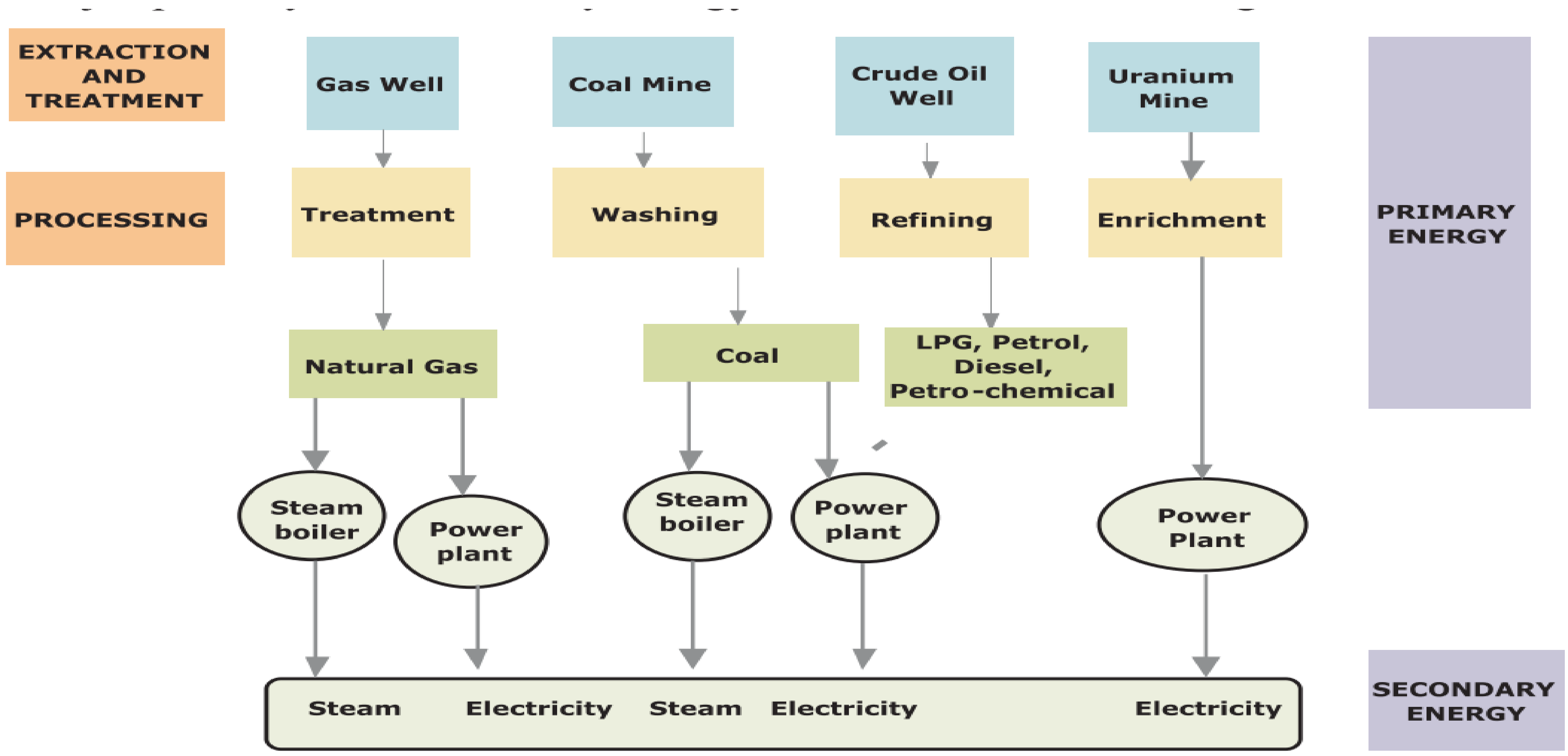


Figure 1.1 Major Primary and Secondary Energy Sources

1.3 Commercial Energy and Non Commercial Energy

Commercial Energy

Energy that is available in the market for a definite price is known as commercial energy. No matter what the method of energy production is, whether it is from fossil fuels, nuclear or renewable sources, any form of energy used for commercial purposes constitutes commercial energy.

By far, the most important forms of commercial energy are electricity, coal, refined petroleum products and natural gas. Commercial energy forms the basis of industrial, agricultural, transport and commercial development in the modern world. In the industrialized countries, commercial fuels are predominant sources of energy not only for industrial use, but also for many household needs.

Examples: Electricity, lignite, coal, oil, natural gas etc.

Non-Commercial Energy

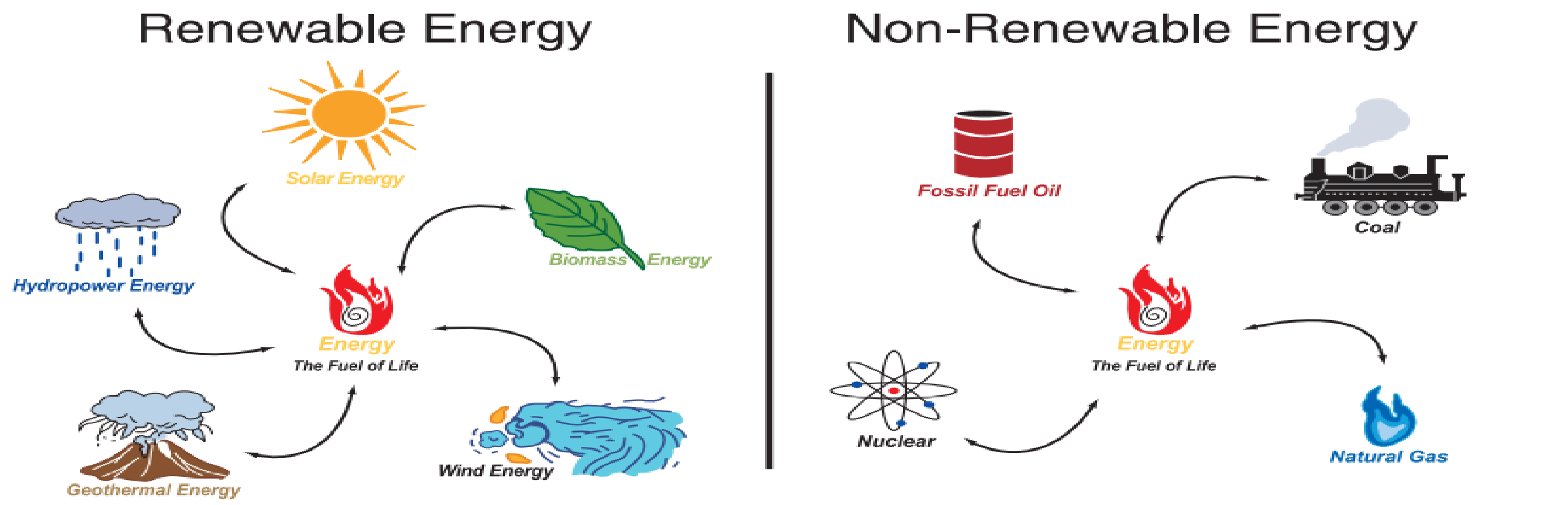
Any kind of energy which is sourced within a community and its surrounding area, and which is not normally traded in the commercial market is termed as non-commercial energy.

Non-commercial energy sources include fuels such as firewood, cattle dung and agricultural wastes, which are traditionally gathered, and used mostly in rural households. These are also called as traditional fuels. Non-commercial energy is often ignored in compiling a country's energy statistics.

1.4 Renewable and Non-Renewable Energy

Renewable energy is the energy obtained from natural sources which are essentially inexhaustible. Examples of renewable resources include wind power, solar power, geothermal energy, tidal power and hydroelectric power (see Figure 1.2). The most important feature of renewable energy is that it can be harnessed without the release of harmful pollutants.

A non-renewable resource is a natural resource which cannot be produced, grown, replenished, or used on a scale which can sustain its consumption rate. These resources often exist in a fixed amount, or are consumed much faster than nature can create them. Natural resources such as coal, oil and natural gas take millions of years to form and cannot be replaced as fast as they are being consumed now. These resources will deplete with time.



Fiscal Year 2019

All values in MTOE

Energy Balance

	Coal	Lignite	Crude	Petroleum Products	Natural Gas	Primary Hydro	Primary Nuclear	Primary Renewables	Electricity	Total
Domestic Production	292.9	12.0	34.2	0.0	23.4	11.6	3.3	11.2	0.0	388.7
Imports	120.1	0.0	226.5	33.3	25.6	0.0	0.0	0.0	0.4	406.0
Exports	0.0	0.0	0.0	61.1	0.0	0.0	0.0	0.0	0.0	61.1
Primary Energy Supply	413.1	12.0	260.7	-27.7	49.0	11.6	3.3	11.2	0.4	733.6
Non-Energy Use	0.0	0.0	0.0	-21.6	-18.3	0.0	0.0	0.0	0.0	-39.9
Statistical Differences	27.9	-0.4	0.0	-1.7	11.9	0.0	0.0	0.0	1.2	38.8
Electricity Plants	-292.8	-10.3	0.0	-0.9	-10.8	-11.6	-3.3	-11.2	141.4	-199.4
Refineries	0.0	0.0	-239.2	239.2	0.0	0.0	0.0	0.0	0.0	0.0
Transformation Losses	0.0	0.0	-21.5	0.0	0.0	0.0	0.0	0.0	-7.4	-28.9
Transport Losses	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-24.3	-24.3
Final Energy Consumption	92.4	2.2	0.0	190.7	16.0	0.0	0.0	0.0	108.9	410.3
Agriculture	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	19.2	20.0
Commercial	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	8.8	11.3
Industry	92.4	2.2	0.0	27.3	4.2	0.0	0.0	0.0	46.7	172.9
Other	0.0	0.0	0.0	91.9	8.2	0.0	0.0	0.0	6.5	106.6
Residential	0.0	0.0	0.0	25.0	0.0	0.0	0.0	0.0	25.9	50.9
Transport	0.0	0.0	0.0	43.4	3.6	0.0	0.0	0.0	1.7	48.7

Power Sector at a Glance ALL INDIA

		Updated on 12-12-2021 **Source: OM SECTION**
1.Total Installed Capacity (As on 30.11.2021) **-** Source : Central Electricity Authority (CEA)		
INSTALLED GENERATION CAPACITY (SECTOR WISE) AS ON 30.11.2021		
Sector	**MW**	**% of Total**
Central Sector	98,547	25.1%
State Sector	1,04,384	26.6%
Private Sector	1,89,087	48.2%
Total	**3,92,017**	

Installed GENERATION CAPACITY(FUELWISE) AS ON 30.11.2021		
CATAGORY	**INSTALLED GENERATION CAPACITY(MW)**	**% of SHARE IN Total**
Fossil Fuel		
Coal	2,02,665	51.7%
Lignite	6,620	1.7%
Gas	24,900	6.4%
Diesel	510	0.1%
Total Fossil Fuel	**2,34,694**	**59.9%**
Non-Fossil Fuel		
RES (Incl. Hydro)	**1,50,544**	38.4%
Hydro	**46,512**	**11.9 %**
Wind, Solar & Other RE	1,04,031	26.5 %
Wind	40,034	10.2 %

Installed GENERATION CAPACITY(FUELWISE) AS ON 30.11.2021		
CATAGORY	**INSTALLED GENERATION CAPACITY(MW)**	**% of SHARE IN Total**
Solar	48,557	12.4 %
BM Power/Cogen	10,176	2.6 %
Waste to Energy	434	0.1 %
Small Hydro Power	4,831	1.2 %
Nuclear	6,780	1.7%
Total Non-Fossil Fuel	**1,57,324**	40.0%
Total Installed Capacity (Fossil Fuel & Non-Fossil Fuel)	**3,92,017**	**100%**

POWER SUPPLY POSITION

3.0 Power Supply Position

The power supply position in the country during 2009-10 to 2021-22 :

	Energy				Peak			
Year	Requirement	Availability	Surplus(+)/Deficts(-)		Peak Demand	Peak Met	Surplus(+) / Deficts(-)	
	(MU)	(MU)	(MU)	(%)	(MW)	(MW)	(MW)	(%)
2009-10	8,30,594	7,46,644	-83,950	-10.1	1,19,166	1,04,009	-15,157	-12.7
2010-	8,61,591	7,88,355	-73,236	-8.5	1,22,287	1,10,256	-12,031	-9.8

11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2011-12	9,37,199	8,57,886	-79,313	-8.5	1,30,006	1,16,191	-13,815	-10.6
2012-13	9,95,557	9,08,652	-86,905	-8.7	1,35,453	1,23,294	-12,159	-9.0
2013-14	10,02,257	9,59,829	-42,428	-4.2	1,35,918	1,29,815	-6,103	-4.5
2014-15	10,68,923	10,30,785	-38,138	-3.6	1,48,166	1,41,160	-7,006	-4.7
2015-16	11,14,408	10,90,850	-23,558	-2.1	1,53,366	1,48,463	-4,903	-3.2
2016-17	11,42,929	11,35,334	-7,595	-0.7	1,59,542	1,56,934	-2,608	-1.6
2017-18	12,13,326	12,04,697	-8,629	-0.7	1,64,066	1,60,752	-3,314	-2.0
2018-19	12,74,595	12,67,526	-7,070	-0.6	1,77,022	1,75,528	-1,494	-0.8
2019-20	12,91,010	12,84,444	-6,566	-0.5	1,83,804	1,82,533	-1,271	-0.7
2020-21	12,75,534	12,70,663	-4,871	-0.4	1,90,198	1,89,395	-802	-0.4
2021-22*	9,20,634	9,16,575	-4059	-0.4	2,03,014	2,00,539	-2,475	-1.2

Energy Needs of Growing Economy

- India's energy demand will increase more than that of any other country over the next two decades, the International Energy Agency (IEA) said on Tuesday forecasting India overtaking the European Union as the world's third-largest energy consumer by 2030.
- India at present is the fourth-largest global energy consumer behind China, the United States and the European Union.
- By 2040, India's power system is bigger than that of the European Union, and is the world's third-largest in terms of electricity generation; it also has 30 per cent more installed renewables capacity than the United States

- By 2040, India is set to account for almost 20 per cent of global growth in industrial value-added, and to lead global growth in industrial final energy consumption, especially in steelmaking. The nation accounts for nearly one-third of global industrial energy demand growth to 2040.
- India's oil demand is seen rising by rise by 74 per cent to 8.7 million barrels per day by 2040 under the existing policies scenario. The natural gas requirement is projected to more than triple to 201 billion cubic meters and coal demand is seen rising to 772 million tonnes in 2040 from the current 590.bal industrial energy demand growth to 2040.

Energy intensity

Energy intensity is the ratio between the gross inland consumption of energy and the gross domestic product (GDP) for a given calendar year. It measures the energy consumption of an economy and its overall energy efficiency.

The gross inland consumption of energy is a measure of the energy inputs to the economy, calculated by adding total domestic energy production plus energy imports minus energy exports plus net withdrawals from existing stocks.

The GDP figures are taken at constant prices to avoid the impact of the inflation, in relation to a base year (say 2000). Since gross inland consumption is measured in toe (tons of oil equivalent) and GDP in millions of US $, this ratio is expressed in toe per million US $.

$$EI = \frac{FC}{GDP}$$

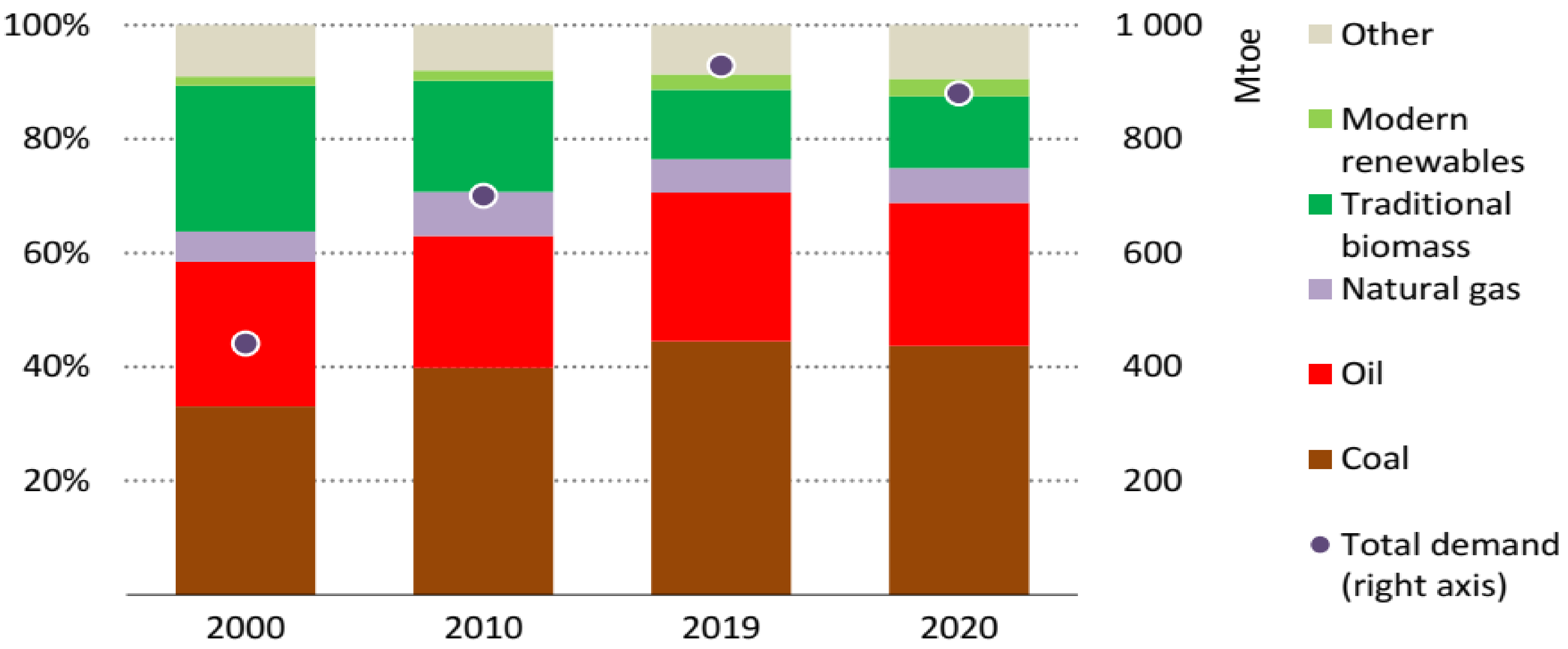
Where:

EI = Energy intensity, national level, toe per million US $
FC = Total final consumption, national level, toe
GDP= Gross domestic product, million US $

Mapping India's energy system

- India's energy needs are largely met by three fuels – coal, oil and biomass
- Oil demand has more than doubled since 2000 as a result of growing vehicle ownership and road transport use
- Transport energy demand grew 3.5 times, while demand in buildings has grown by 40% since 2000.
- Electricity consumption has nearly tripled over the past two decades – growing faster than total energy demand.
- Solar PV and wind accounted for 18% of the capacity mix in 2019, but their combined share of generation was less than 10%.

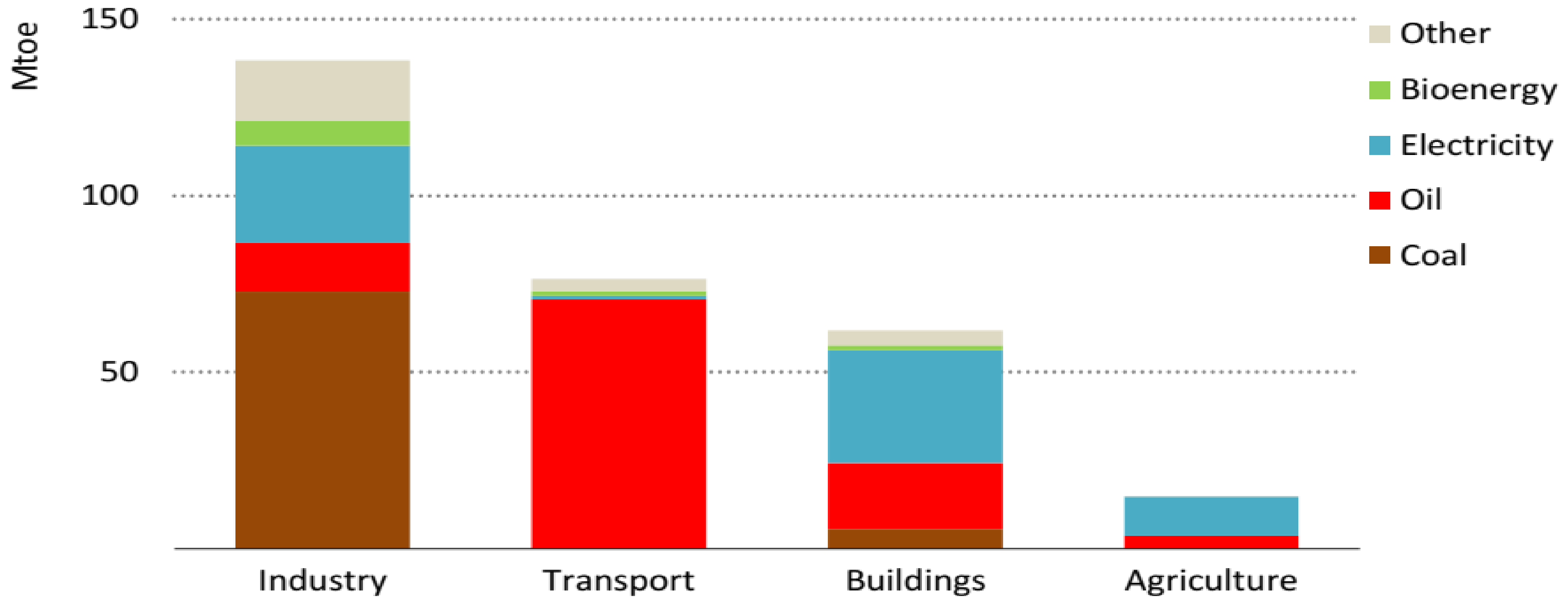
Total primary energy demand in India



India's energy demand has tripled over the last three decades: the share of traditional biomass has fallen, leaving coal and oil dominant.

Note: Mtoe = million tonnes of oil equivalent.

Change in energy demand by fuel in selected end-use sectors



Among end-use sectors, the growth in energy demand has been larger in industries than in transport and buildings, and this growth has largely been fuelled by coal.

Figure 1.6 ▻ Final energy consumption per capita by state, 2018

Energy and economic indicators in selected states in India, 2018

	Urban population (million)	Rural population (million)	GDP per capita (PPP) ($)	Total final consumption per capita (toe)	Electricity demand per capita (kWh)
Higher income	192.7	233.8	12 159	0.6	1 615
Delhi	16.4	0.4	19 970	0.6	1 548
Haryana	8.8	16.5	12 900	0.8	2 082
Telangana	13.6	21.4	11 170	0.5	1 896
Karnataka	23.6	37.5	11 520	0.6	1 396
Kerala	15.9	17.5	11 150	0.5	757
Gujarat	25.7	34.7	10 790	1.1	2 378
Uttarakhand	3.0	7.0	10 860	0.5	1 467
Maharashtra	50.8	61.6	10 480	0.5	1 424
Tamil Nadu	34.9	37.2	10 590	0.5	1 866
Middle income	84	220.6	6 540	0.5	1 129
Punjab	10.4	17.3	8 470	0.6	2 046
Andhra Pradesh	14.6	35	8 260	0.5	1 480
Rajasthan	17	51.5	6 040	0.5	1 282
West Bengal	29.1	62.2	5 980	0.4	703
Chhattisgarh	5.9	19.6	5 290	1.0	1 961
Odisha	7	35	5 200	1.0	1 628
Lower income	88.7	352.1	3 930	0.3	647
Madhya Pradesh	20.1	52.6	4 970	0.4	1 084
Assam	4.4	26.8	4 490	0.3	341
Jharkhand	7.9	25.1	4 150	0.6	938
Uttar Pradesh	44.5	155.3	3 640	0.3	606
Bihar	11.8	92.3	2 400	0.2	311

Notes: kWh = kilowatt-hours. Delhi is a union territory rather than a state but is included here as the capital of India.
Source: IEA analysis, MoSPI (2020)

Energy Pricing in India

- Price of energy does not reflect true cost to society. The basic assumption underlying efficiency of market place does not hold in our economy, since energy prices are undervalued and energy wastages are not taken seriously. Pricing practices in India like many other developing countries are influenced by political, social and economic compulsions at the state and central level.

More often than not, this has been the foundation for energy sector policies in India. The Indian energy sector offers many examples of cross subsidies e.g., diesel, LPG and kerosene being subsidised by petrol, petroleum products for industrial usage and industrial, and commercial consumers of electricity subsidising the agricultural and domestic consumers.

Energy Pricing in India

- Electricity tariffs in India are structured in a relatively simple manner. While high tension consumers are charged based on both demand (kVA) and energy (kWh), the low-tension (LT) consumer pays only for the energy consumed (kWh) as per tariff system in most of the electricity
  boards. The price per kWh varies significantly across States as well as customer segments within a State. Tariffs in India have been modified to consider the time of usage and voltage level
  of supply. In addition to the base tariffs, some State Electricity Boards have additional recovery from customers in form of fuel surcharges, electricity duties and taxes

Energy and Environment

The usage of energy resources in industry leads to environmental damages by polluting the atmosphere. Few of examples of air pollution are sulphur dioxide (SO_2), nitrous oxide (NO_X) and carbon monoxide (CO) emissions from boilers and furnaces, chloro-fluro carbons (CFC) emissions from refrigerants use, etc. In chemical and fertilizers industries, toxic gases are released. Cement plants and power plants spew out particulate matter. Typical inputs, outputs, and emissions for a typical industrial process are shown in Figure 1.10.

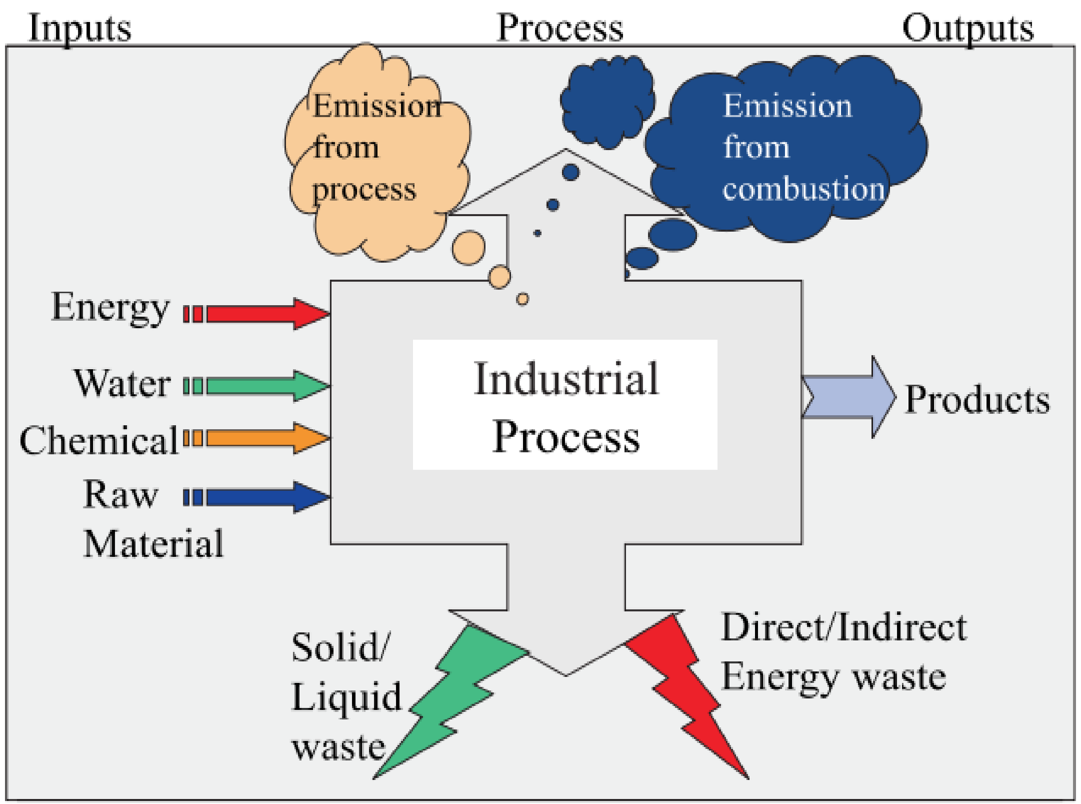


Figure 1.10 Inputs & Outputs of Process

Principle Pollutants

The principle pollutants produced by industrial, domestic and traffic sources are

- Sulphur dioxide
- Nitrogen oxides
- Acidification from SO2 and NO
- Carbon monoxide (CO)
- Ground-level ozone (O3)
- Hydrocarbons
- TOMPs (Toxic Organic Micropollutants)
- Heavy Metals and Lead

3.1 Definition & Objectives of Energy Management

The fundamental goal of energy management is to produce goods and provide services with the least cost and least environmental effect.

The term energy management means many things to many people. One definition of energy management is:

> *"The judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions"*
>
> (Cape Hart, Turner and Kennedy, Guide to Energy Management Fairmont press inc. 1997)

Another comprehensive definition is

> "The strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems"

The objective of Energy Management is to achieve and maintain optimum energy procurement and utilisation, throughout the organization and:

- To minimise energy costs / waste without affecting production & quality
- To minimise environmental effects.

Energy Audit: Types And Methodology

- *What is Energy audit?*

As per the Energy Conservation Act, 2001, Energy Audit is defined as "the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption".

Need for Energy Audit

In any industry, the three top operating expenses are often found to be

- Energy (both electrical and thermal)
- Labour
- Materials

- Energy Audit will help to understand more about the ways energy and fuel are used in any industry, and help in identifying the areas where waste can occur and where scope for improvement exists

- The Energy Audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programmes which are vital for production and utility activities.

- Energy Audit provides a " bench-mark“ (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.

Type of Energy Audit

The type of Energy Audit to be performed depends on:

- Function and type of industry
- Depth to which final audit is needed, and
- Potential and magnitude of cost reduction desired

Thus Energy Audit can be classified into the following two types.

i) Preliminary Audit

ii) Detailed Audit

3.2.3 Preliminary Energy Audit Methodology

Preliminary energy audit is a relatively quick exercise to:

- Establish energy consumption in the organization
- Estimate the scope for saving
- Identify the most likely (and the easiest areas for attention
- Identify immediate (especially no-/low-cost) improvements/ savings
- Set a 'reference point'
- Identify areas for more detailed study/measurement
- Preliminary energy audit uses existing, or easily obtained data

Detailed Energy Audit Methodology

A comprehensive audit provides a detailed energy project implementation plan for a facility, since it evaluates all major energy using systems.

This type of audit offers the most accurate estimate of energy savings and cost. It considers the interactive effects of all projects, accounts for the energy use of all major equipment, and includes detailed energy cost saving calculations and project cost.

In a comprehensive audit, one of the key elements is the energy balance. This is based on an inventory of energy using systems, assumptions of current operating conditions and calculations of energy use. This estimated use is then compared to utility bill charges.

Detailed energy auditing is carried out in three phases: Phase I, II and III.

Phase I - Pre Audit Phase
Phase II - Audit Phase
Phase III - Post Audit Phase

Step No	PLAN OF ACTION	PURPOSE / RESULTS
	Phase I –Pre Audit Phase	
Step 1	• Plan and organise • Walk through Audit • Informal Interview with Energy Manager, Production / Plant Manager	• Resource planning, Establish/organize a Energy audit team • Organize Instruments & time frame • Macro Data collection (suitable to type of industry.) • Familiarization of process/plant activities • First hand observation & Assessment of current level operation and practices
Step 2	• Conduct of brief meeting / awareness programme with all divisional heads and persons concerned (2-3 hrs.)	• Building up cooperation • Issue questionnaire for each department • Orientation, awareness creation
	Phase II –Audit Phase	
Step 3	• Primary data gathering, Process Flow Diagram, & Energy Utility Diagram	• Historic data analysis, Baseline data collection • Prepare process flow charts • All service utilities system diagram (Example: Single line power distribution diagram, water, compressed air & steam distribution. • Design, operating data and schedule of operation • Annual Energy Bill and energy consumption pattern (Refer manual, log sheet, name plate, interview)
Step 4	• Conduct survey and monitoring	• Measurements : Motor survey, Insulation, and Lighting survey with portable instruments for collection of more and accurate data. Confirm and compare operating data with design data.
Step 5	• Conduct of detailed trials /experiments for selected energy guzzlers	• Trials/Experiments: – 24 hours power monitoring (MD, PF, kWh etc.). – Load variations trends in pumps, fan compressors etc.

		- Boiler/Efficiency trials for (4 – 8 hours) - Furnace Efficiency trials Equipments Performance experiments etc
Step6	• Analysis of energy use	• Energy and Material balance & energy loss/waste analysis
Step 7	• Identification and development of Energy Conservation (ENCON) opportunities	• Identification & Consolidation ENCON measures • Conceive, develop, and refine ideas • Review the previous ideas suggested by unit personal • Review the previous ideas suggested by energy audit if any • Use brainstorming and value analysis techniques • Contact vendors for new/efficient technology
Step 8	• Cost benefit analysis	• Assess technical feasibility, economic viability and prioritization of ENCON options for implementation • Select the most promising projects • Prioritise by low, medium, long term measures
Step9	• Reporting & Presentation to the Top Management	• Documentation, Report Presentation to the top Management.
	Phase III –Post Audit phase	
Step10	• Implementation and Follow-up	Assist and Implement ENCON recommendation measures and Monitor the performance • Action plan, Schedule for implementation • Follow-up and periodic review

Phase I -Pre Audit Phase Activities

A structured methodology to carry out an energy audit is necessary for efficient working. An initial study of the site should always be carried out, as the planning of the procedures necessary for an audit is most important.

Initial Site Visit and Preparation Required for Detailed Auditing

An initial site visit may take one day and gives the Energy Auditor/Engineer an opportunity to meet the personnel concerned, to familiarize him with the site and to assess the procedures necessary to carry out the energy audit.

During the initial site visit the Energy Auditor/Engineer should carry out the following actions: -

- Discuss with the site's senior management the aims of the energy audit.
- Discuss economic guidelines associated with the recommendations of the audit.
- Analyse the major energy consumption data with the relevant personnel.
- Obtain site drawings where available - building layout, steam distribution, compressed air distribution, electricity distribution etc.
- Tour the site accompanied by engineering/production

The main aims of this visit are: -

- To finalise Energy Audit team
- To identify the main energy consuming areas/plant items to be surveyed during the audit.
- To identify any existing instrumentation/ additional metering required.
- To decide whether any meters will have to be installed prior to the audit eg. kWh, steam, oil or gas meters.
- To identify the instrumentation required for carrying out the audit.
- To plan with time frame
- To collect macro data on plant energy resources, major energy consuming centers
- To create awareness through meetings/ programme

Phase II- Detailed Energy Audit Activities

Depending on the nature and complexity of the site, a comprehensive audit can take from several weeks to several months to complete. Detailed studies to establish, and investigate, energy and material balances for specific plant departments or items of process equipment are carried out. Whenever possible, checks of plant operations are carried out over extended periods of time, at nights and at weekends as well as during normal daytime working hours, to ensure that nothing is overlooked.

The audit report will include a description of energy inputs and product outputs by major department or by major processing function, and will evaluate the efficiency of each step of the manufacturing process. Means of improving these efficiencies will be listed, and at least a preliminary assessment of the cost of the improvements will be made to indicate the expected payback on any capital investment needed. The audit report should conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be performed to justify the implementation of those conservation measures that require investments.

The information to be collected during the detailed audit includes: -

1. Energy consumption by type of energy, by department, by major items of process equip ment, by end-use
2. Material balance data (raw materials, intermediate and final products, recycled materials, use of scrap or waste products, production of by-products for re-use in other industries, etc.)
3. Energy cost and tariff data
4. Process and material flow diagrams
5. Generation and distribution of site services (eg.compressed air, steam).
6. Sources of energy supply (e.g. electricity from the grid or self-generation)
7. Potential for fuel substitution, process modifications, and the use of co-generation systems (combined heat and power generation).
8. Energy Management procedures and energy awareness training programs within the establishment.

Existing baseline information and reports are useful to get consumption pattern, production cost and productivity levels in terms of product per raw material inputs. The audit team should collect the following baseline data:

- Technology, processes used and equipment details
- Capacity utilisation
- Amount & type of input materials used
- Water consumption
- Fuel Consumption
- Electrical energy consumption
- Steam consumption
- Other inputs such as compressed air, cooling water etc
- Quantity & type of wastes generated
- Percentage rejection / reprocessing

Role of Energy Managers

1. Prepare an annual activity plan and present to management concerning financially attractive investments to reduce energy costs.
2.Establish an energy conservation cell within the firm with management's consent about the mandate and task of the cell.
3.Initiate activities to improve monitoring and process control to reduce energy costs.
4.Analyze equipment performance with respect to energy efficiency.
5.Ensure proper functioning and calibration of instrumentation required to assess level of energconsumption directly or indirectly.
6.Prepare information material and conduct internal workshops about the topic for other staff.

Role of Energy Managers

7.Improve disaggregating of energy consumption data down to shop level or profit center of a firm.

8.Establish a methodology how to accurately calculate the specific energy consumption of various products/services or activity of the firm.

9.Develop and manage training programme for energy efficiency at operating levels.

10.Co-ordinate nomination of management personnel to external programs.

11.Create knowledge bank on sectoral, national and international development on energy efficiency technology and management system and information denomination.

Role of Energy Managers

12.Develop integrated system of energy efficiency and environmental upgradation, Wide internal & external networking.
13.Co-ordinate implementation of energy audit/efficiency improvement projects through external agencies.
14.Establish and/or participate in information exchange with other energy managers of the same sector through association.

Key instruments for Energy Audit

Electrical Measuring Instruments:

These are instruments for measuring major electrical parameters such as kVA, kW, PF, Hertz, kVAr, Amps and Volts. In addition some of these instruments also measure harmonics.

These instruments are applied on-line i.e on running motors without any need to stop the motor. Instant measurements can be taken with hand-held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals.

	**Combustion analyzer:** This instrument has in-built chemical cells which measure various gases such as O_2, CO, NO_x and SO_x.
	**Fuel Efficiency Monitor:** This measures oxygen and temperature of the flue gas. Calorific values of common fuels are fed into the microprocessor which calculates the combustion efficiency.

	**Fyrite:** A hand bellow pump draws the flue gas sample into the solution inside the fyrite. A chemical reaction changes the liquid volume revealing the amount of gas. A separate fyrite can be used for O2 and CO_2 measurement.
	**Contact thermometer:** These are thermocouples which measures for example flue gas, hot air, hot water temperatures by insertion of probe into the stream. For surface temperature, a leaf type probe is used with the same instrument.
	**Infrared Thermometer:** This is a non-contact type measurement which when directed at a heat source directly gives the temperature read out. This instrument is useful for measuring hot spots in furnaces, surface temperatures etc.

	**Pitot Tube and manometer:** Air velocity in ducts can be measured using a pitot tube and inclined manometer for further calculation of flows.
	**Water flow meter:** This **non-contact** flow measuring device using Doppler effect / Ultra sonic principle. There is a transmitter and receiver which are positioned on opposite sides of the pipe. The meter directly gives the flow. Water and other fluid flows can be easily measured with this meter.

 Tachometer	 Stroboscope	**Speed Measurements:** In any audit exercise speed measurements are critical as they may change with frequency, belt slip and loading. A simple tachometer is a contact type instrument which can be used where direct access is possible. More sophisticated and safer ones are non contact instruments such as stroboscopes.
		**Leak Detectors:** Ultrasonic instruments are available which can be used to detect leaks of compressed air and other gases which are normally not possible to detect with human abilities.
		**Lux meters:** Illumination levels are measured with a lux meter. It consists of a photo cell which senses the light output, converts to electrical impulses which are calibrated as lux.

Energy Conservation

What is Energy Conservation?

Energy Conservation and Energy Efficiency are separate, but related concepts. Energy conservation is achieved when growth of energy consumption is reduced, measured in physical terms. Energy Conservation can, therefore, be the result of several processes or developments, such as productivity increase or technological progress. On the other hand Energy efficiency is achieved when energy intensity in a specific product, process or area of production or consumption is reduced without affecting output, consumption or comfort levels. Promotion of energy efficiency will contribute to energy conservation and is therefore an integral part of energy conservation promotional policies.

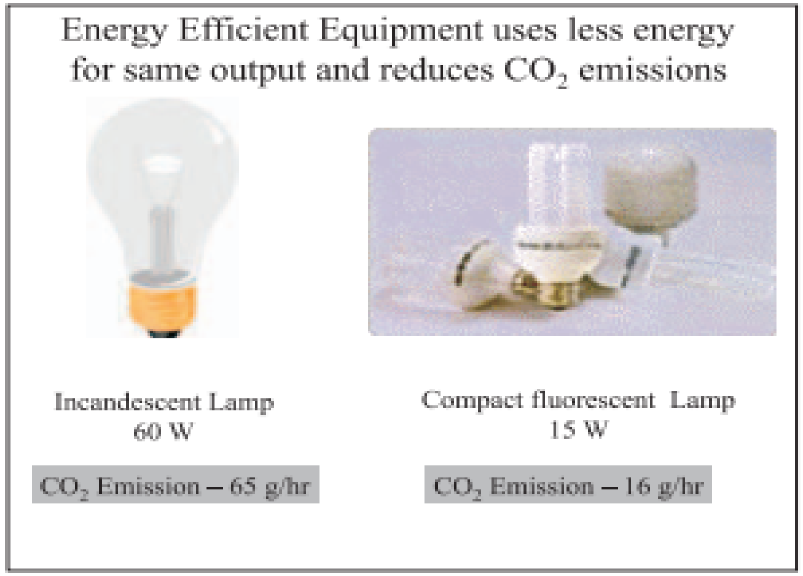


Figure 1.14

Energy efficiency is often viewed as a resource option like coal, oil or natural gas. It provides additional economic value by preserving the resource base and reducing pollution. For example, replacing traditional light bulbs with Compact Fluorescent Lamps (CFLs) means you will use only 1/4th of the energy to light a room. Pollution levels also reduce by the same amount (refer Figure 1.14).

Energy Efficiency Benefits

Industry	Nation	Globe
		
• Reduced energy bills • Increased Competitiveness • Increased productivity • Improved quality • Increased profits !	• Reduced energy imports • Avoided costs can be used for poverty reduction • Conservation of limited resources • Improved energy security	• Reduced GHG and other emissions • Maintains a sustainable environment