Energy Efficiency Training – Mozambique

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UNEP DTU PARTNERSHIP | COPENHAGEN CENTRE ON ENERGY EFFICIENCY
SEforALL EE HUB

ELECTRICIDADE DE MOCAMBIQUE, E.P.

Scheduled Topics

Day	Module	Topic
12 November 2020	1.1	What is Energy Efficiency
16 November 2020	1.3	EE Strategic Planning – Part 1
19 November 2020	1.4	Energy Audit and Management
24 November 2020	**2.2**	**Energy Audit and Management for Buildings**
26 November 2020	2.5	Energy Efficiency - HVAC systems

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Energy Audit and Management – for Buildings

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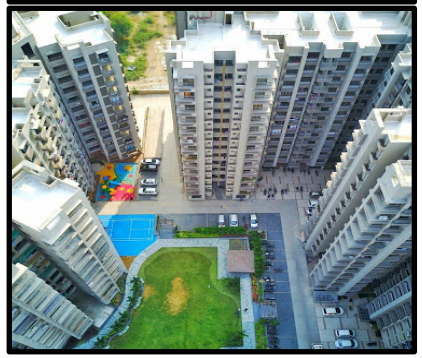
Types of buildings

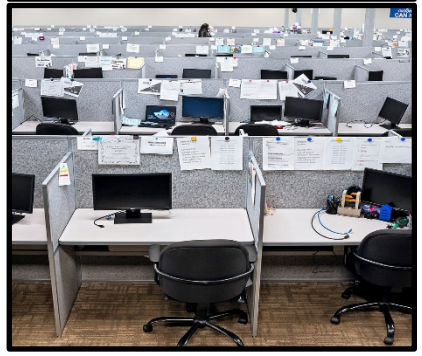
Residential



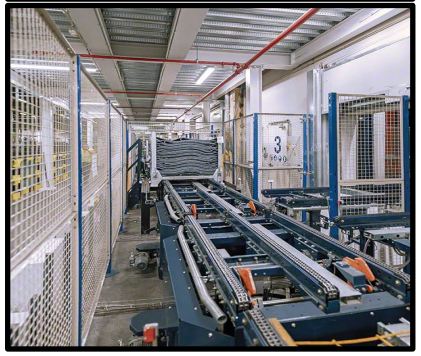
Educational

Healthcare

Office/Business



Industrial



Storage

… and many more

Energy Audit and Management for Buildings– How ?

Energy Management - Buildings

Energy Management

Energy management success depends on -

- Technical ability
- Monitoring system
- Strategy plan
- Top Management support

Source: BEE India;

Energy Management

Technical ability

- Energy terminologies
- Systems installed – Envelope, the passive and active components

Source: BEE India;

Energy Management

- Efficiencies and Performances –
  - insulation health,
  - Lighting lux levels
  - HVAC efficiency
- Building Management System in place?

Monitoring system

Source: BEE India;

Energy Management

- Defined objectives and goals
- Clear steps to achieve those goals

Strategy plan

Source: BEE India;

Energy Management

- Management support to initiate.

Top Management support

Source: BEE India;

Energy Management

Management's commitment and support

- Building Energy Manager
- Energy Team (engineering/procurement/admin/facility management/contractors etc.)
- Energy policy

Energy performance assessment

- BMS
- Baseline and benchmark EPI (kWh/m^2/year), efficiencies, energy consumption and costs.
- Energy audits and performance evaluation

Goal setting

- Defined scope and established goals
- Estimate improvement potential

Source: BEE India;

Energy Management

Create action plan

- Roles and responsibilities
- Technical steps

Implement action plan

- Communicate
- Awareness and capacity building
- Motivate

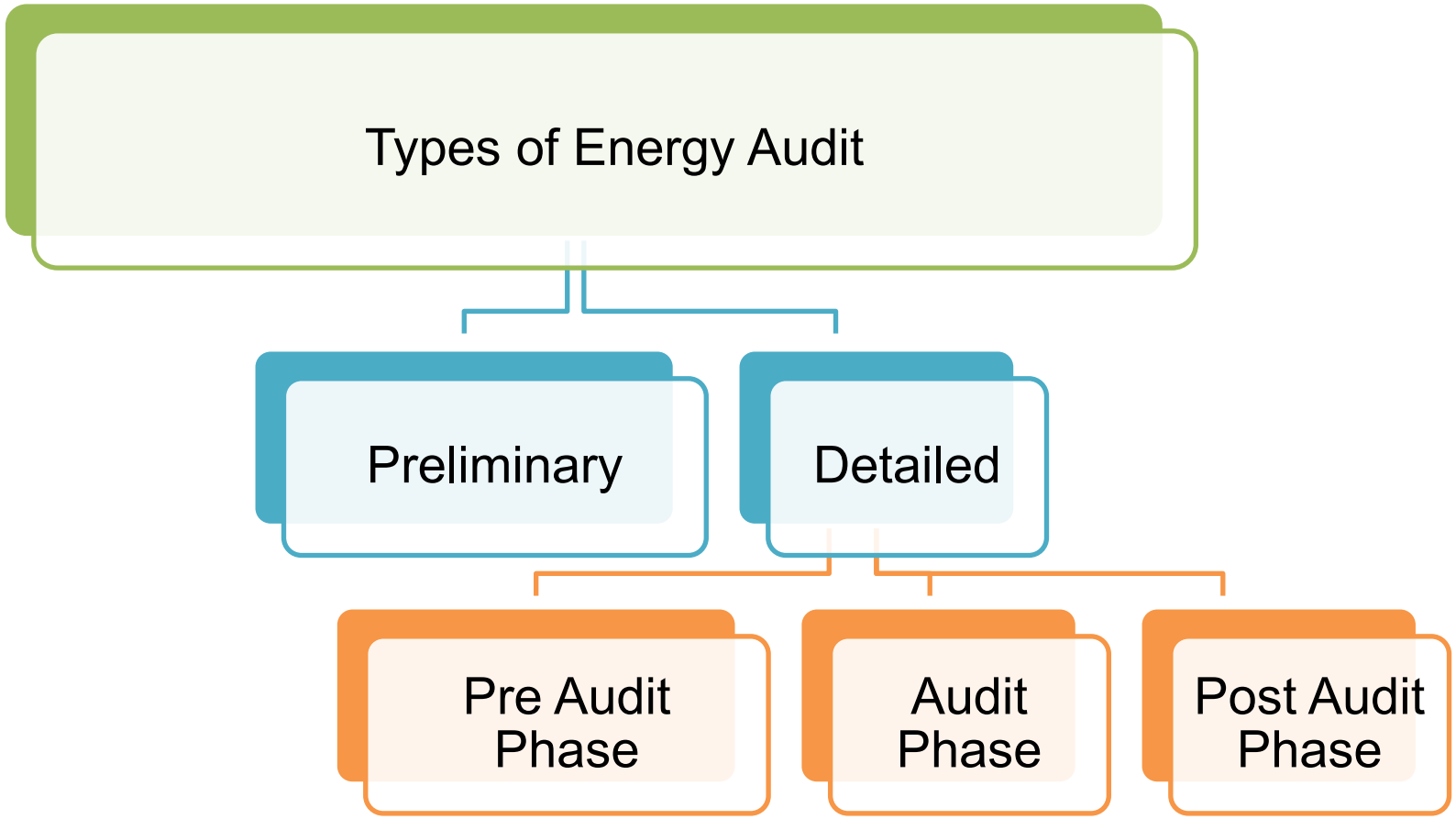
Progress evaluation and recognition

- Measure results
- Review data, benchmarks and action plans
- Recognition

Source: BEE India;

Energy Audit - Buildings

Energy Audit – How?



Preliminary Energy Audit

Preliminary Energy Audit

Source: https://images.app.goo.gl/pHaHToWfT1ykMkjY6;

Example: Energy Efficiency in municipal buildings

- Types of buildings – Residential complexes / commercial / educational / institutional / office / industrial.

Preliminary Energy Audit - steps

Establish energy consumption

- Annual energy consumption (electricity, gas, etc.)
- EPI kWh/m^2/year
- Major energy consumption areas.

Scope for saving

- Technology (eg. FTL, LED, CFL)
- Age
- Application (eg. Space heating, cooking, hot water, cooling)

Low hanging fruits

- Replacement to EE light fittings
- Better labeling of AC units
- EE motors
- Window type (pane, glazing, shading, etc.)
- Insulation (wall, roof, pipelines, etc.)

In-depth study areas

- HVAC performances
- Pump efficiencies
- Simulations for heat and cooling load optimization

Reference point

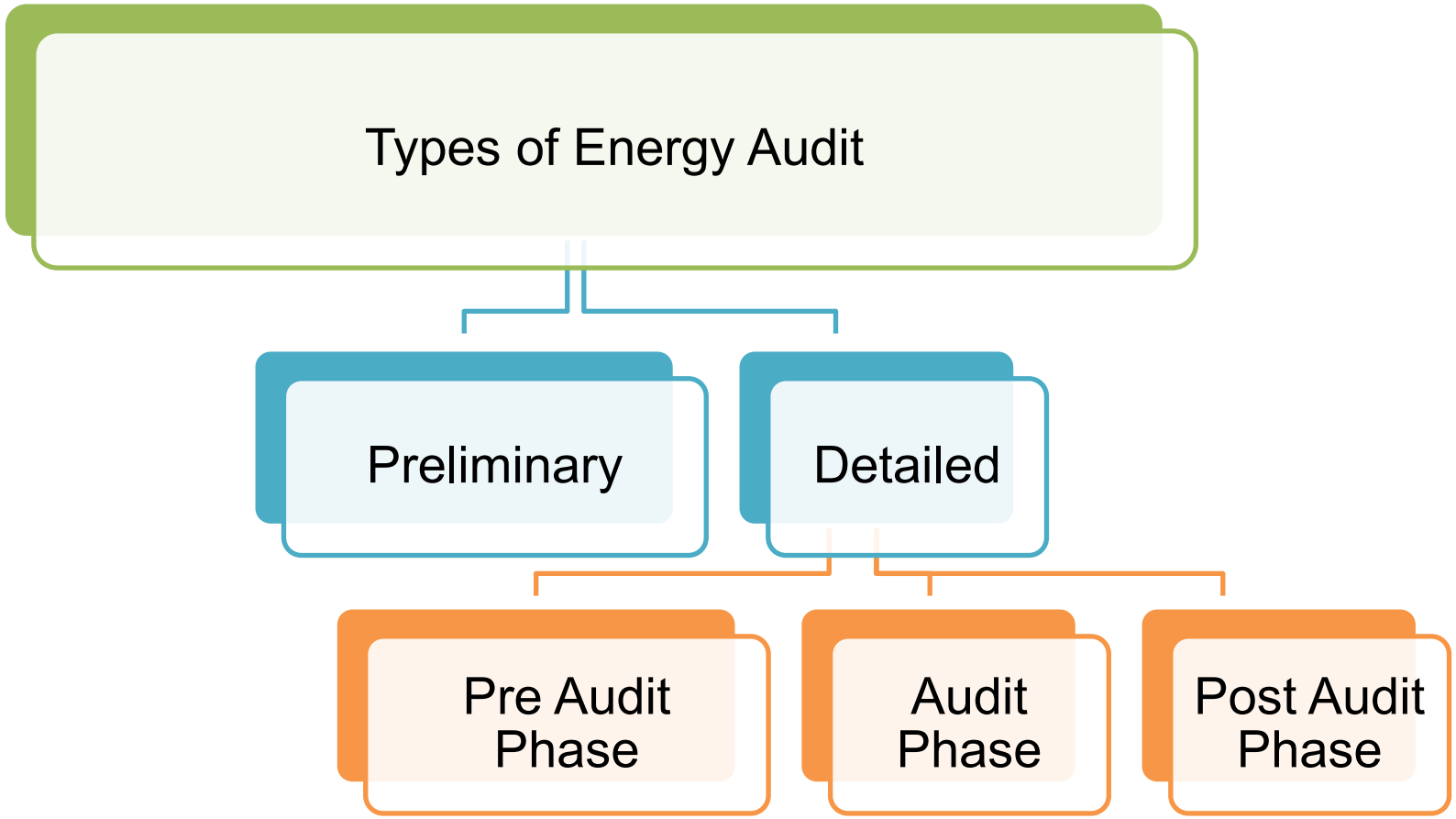
- EPI baseline (w.r.t. energy load, technology, building type, etc.)

Preliminary Energy Audit - steps

Building type	Total numbers	Energy consumption	Potential energy savings	Scope areas
Residential complexes	20			
Industrial buildings /storage/warehouses	5			
Office buildings	50		HIGHEST ?	Lighting HVAC insulation
Commercial / retail / wholesale /malls	15			Lighting, HVAC
Educational	5		LOWEST?	lighting
Healthcare	5			
Etc.				

Note: value and content in the table is for example and are not actual

Energy Audit – How?



Detailed Energy Audit

Energy Audit Instruments

Energy audit instruments

- Power analyzers
- Anemometer
- Multi-function kit – (T, RH, P, etc.)
- Ultrasonic water flow meter
- Infra-red thermohunter
- Thermograph
- Lux meter
- Data loggers
- CO2 meters

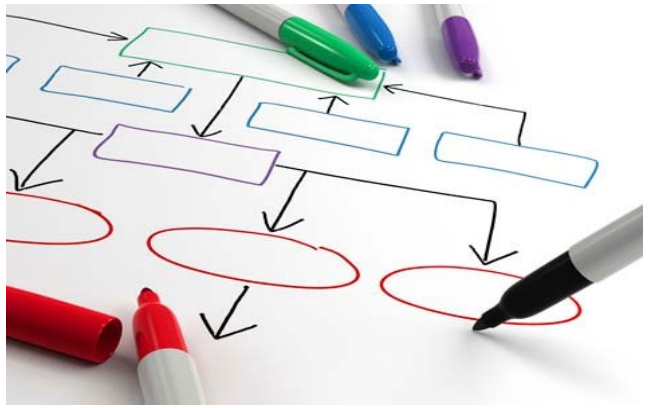
Source: TERI, India

Pre Audit Phase

Detailed Energy Audit

Detailed Energy Audit – Pre Audit Phase

- Step 1
- Step 2
- Step 3
- Step 4
- Step 5
- Step 6
- Step 7
- Step 8
- Step 9
- Step 10



Plan & organize

Walk-through audit

Interview with energy manager, facility or production manager

Resource planning	Macro data	Familiarize

Source: BEE India; https://images.app.goo.gl/PkvESzzmrv41D5v28; https://images.app.goo.gl/ktbEAekhmmrbj1QWA; https://images.app.goo.gl/UsEExKYqwoM1tyBq6;

Detailed Energy Audit – Pre Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Questionnaire – Building details

	Study facility	Head Quarters/Office
Name & Address of Company	M/s ABC .Ltd	
Phone No.		
Email		
Contact person name		
Designation & phone		
Type of facility	Hotel	
Capacity		

Detailed Energy Audit – Pre Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Questionnaire – energy sources

Source	Year 2020-21		Year 2019-20		Major Consumption
	Qty	Cost (local currency)	Qty	Cost (local currency)	Points
Electricity	78,77,871 kWh	6,45,98542	71,49,613	5,86,26827	Chillers & pumps
FO/LSHS					
Coal / LPG / NATURAL GAS					
HSD					
Others					
Occupancy levels	2500 / day		1800 / day		Kitchen, banquet halls.
Aux power					

Detailed Energy Audit – Pre Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Questionnaire – energy sources

Parameter	Value
Contract demand, kVA	
Demand charges, $/kVA	
Unit charges, $/kWh	
Average power factor	0.99
Total capacitor bank capacitance installed, kVAR	3622
Location of capacitors	PCC and MCC rooms
Etc.	

Detailed Energy Audit – Pre Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Questionnaire – equipment and components

Transformers:

No. of transformers & type	Capacity	Location	Incoming Voltage	Supply Voltage	OLTC Details
3 no's oil immersed type	2.5 MVA	S-11 transformer yard	11 KV	415 V	NA

Motors:

Size	kW Range	Nos.				Operating
		SC	Slipring	Synchro-nous	D.C	h/y
Utility Cooling tower motor(2nos)	37	Yes				8760
210 TR chiller pump motors(2 no's)	30	Yes				8760

Detailed Energy Audit – Pre Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Questionnaire – equipment and components

HVAC systems:

Unit capacity TR	Compressor Type / VAU	Make & Model	Application & desired condition	Energy consumption per year
210 TR	Compressor	Daikin(PFS 2202DARY)	Chilled water supply	4,60,417
200 TR	Compressor	King Air(KCWF2 200A1)	Chilled water supply	67,056

Motors:

Detailed Energy Audit – Pre Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Questionnaire – equipment and components

Similar data collection for

- Fans and blowers
- Cooling towers
- Lighting‘
- Boilers and steam or hot water generators
- Diesel generator sets (if any)
- Building envelope details (area, orientation, insulation, material, windows, glazing, shading, roof reflective coating etc.)

Detailed Energy Audit – Pre Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

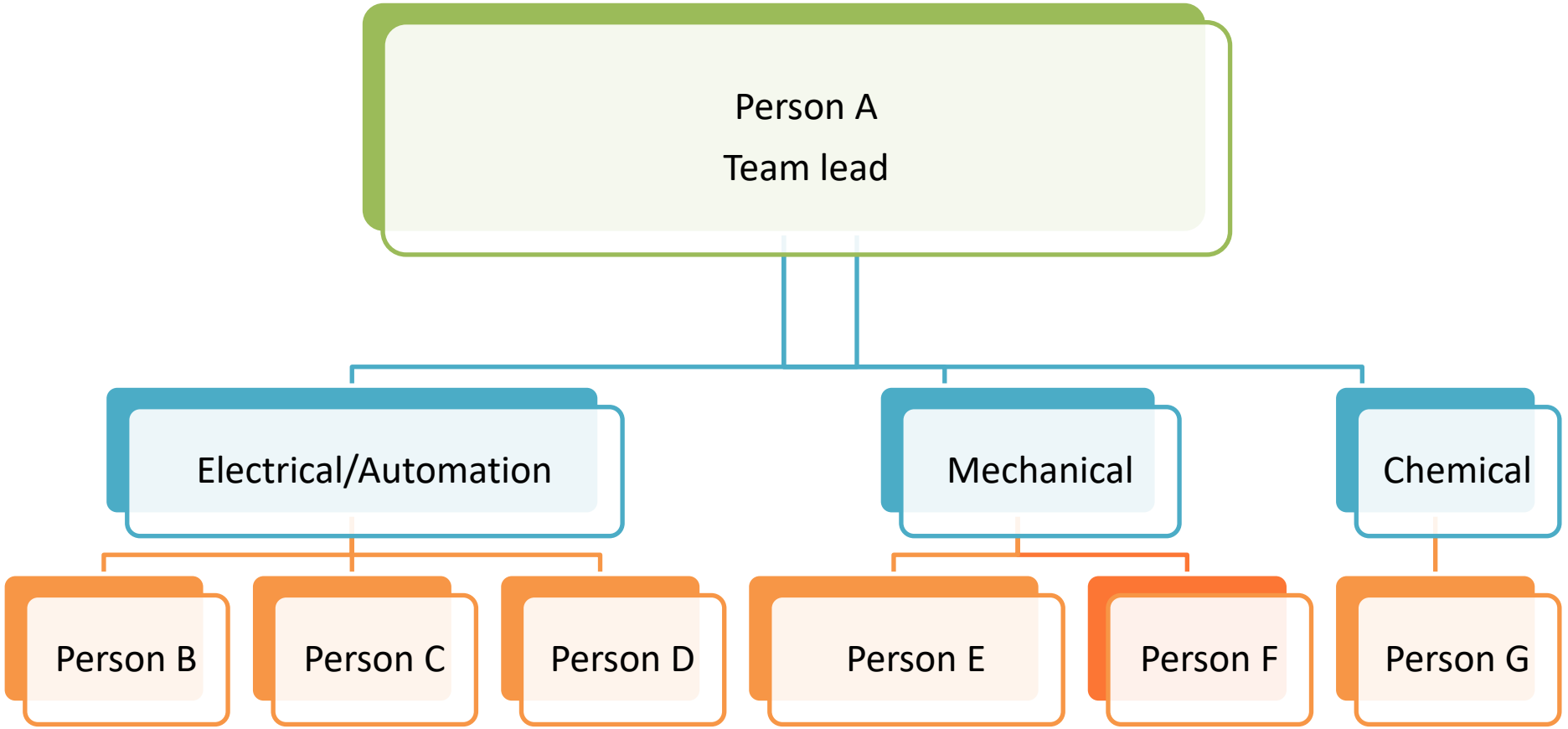
Resource planning and allocation - Instruments

S No	Description	Numbers	Functions
1	Krykard ALM 32 power analyser	4	Three phase power and harmonic analysers
2	Krykard ALM 10 power analyser	1	Single phase power and harmonic analysers
3	Fluke-41B power analyser	2	Power and harmonic analysers
4	Anemometer	2	Air flow measurements
5	Multifunction kit	1	RH%, Temperature, Pressure, flow
6	Lux meter	2	Illumination levels
7	Ultrasonic flow meter	1	Water flow measurements
8	Infra-red pyrometer	1	Surface temperature measurements

Detailed Energy Audit – Pre Audit Phase

- Step 1
- Step 2
- Step 3
- Step 4
- Step 5
- Step 6
- Step 7
- Step 8
- Step 9
- Step 10

Resource planning and allocation - Professionals



Detailed Energy Audit – Pre Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Resource planning and allocation - Professionals

Day		Date	Electrical 1	Electrical 2	Thermal 2	Thermal 2 and 3
Day 1	Tue	25-Jun-21	Walk through			
			2 Transformers (3150 kVA each) + and other required panel loggings	3 chillers + aux + AHUs	3 chillers + aux + AHUs	AHUs (98 no's total) + VRV + VAU
Day 2	Wed	26-Jun-21	2 Transformers (3150 kVA each) + and other required panel loggings	AHUs + VRV + VAU	3 chillers + aux + process and utility CT	AHUs (98 no's total) + VRV + VAU
Day 3	Thu	27-Jun-21	DGs / lighting internal	VP+ fans and other drives+ Air compressor logging	Fans / Vacuum pumps (5no.s) + air compresser	Process and user end compressor + chilled water
Day 4	Fri	28-Jun-21	Systems electrical assessment	remaining process and utility drives	Process and user end compressor + chilled water	Process and user end compressor + chilled water
Day 5	Sat	29-Jun-21	interim discussion / pending works/Material exit	interim discussion / pending works/Material exit	interim discussion / pending works/Material exit	interim discussion / pending works/Material exit

Detailed Energy Audit – Pre Audit Phase

- Step 1
- Step 2
- Step 3
- Step 4
- Step 5
- Step 6
- Step 7
- Step 8
- Step 9
- Step 10

Resource planning and allocation - Milestones

Activity	Tentative dates	Weeks							
		1	2	3	4	5	6	7	8
Preliminary visit	10-Jun-21								
Kick-off meeting	14-Jun-21								
Building 1 Field study	17-Jun-21 to 24-Jun-21								
Building 2 Field study	25-Jun-21 to 28-Jun-21								
Post field study presentations	02-Jul-21								
Report preparation	3-Jul-21 to 31-Jul-21								
Closing final presentation	First week of August								

Detailed Energy Audit – Pre Audit Phase

- Step 1
- Step 2
- Step 3
- Step 4
- Step 5
- Step 6
- Step 7
- Step 8
- Step 9
- Step 10

Conduct kick-off meeting – Divisional heads, associated and concerned personnel

- Cooperation
- Interaction
- Create awareness

Source: BEE India; https://images.app.goo.gl/Vg2PWNz1apkNv6BeA;

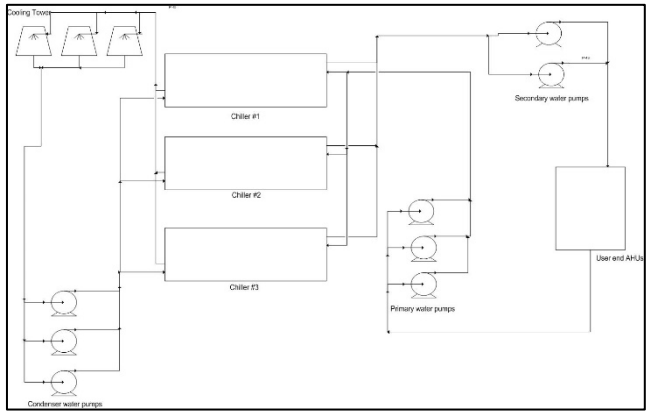
Audit Phase

Detailed Energy Audit

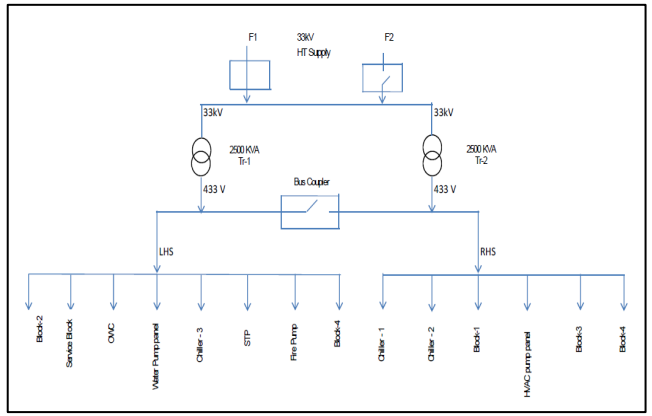
Detailed Energy Audit – Audit Phase

- Step 1
- Step 2
- Step 3
- Step 4
- Step 5
- Step 6
- Step 7
- Step 8
- Step 9
- Step 10

Collect primary data



Flow diagrams



Energy utility diagrams

Historic and baseline data

Flow charts and utility diagrams

Energy bill and consumption pattern

Source: BEE India; https://images.app.goo.gl/sazMnrCe76HXqjeKA;

Detailed Energy Audit – Audit Phase

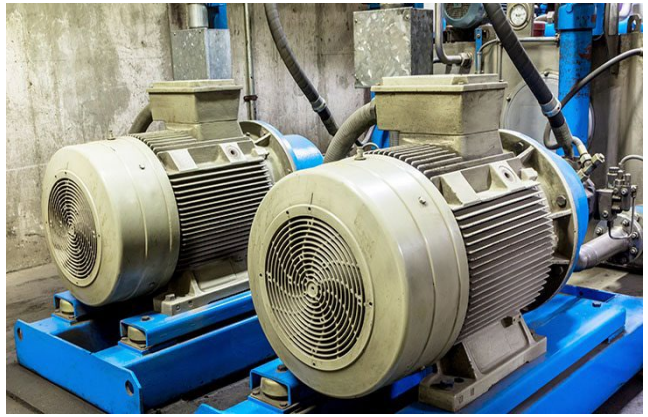
Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

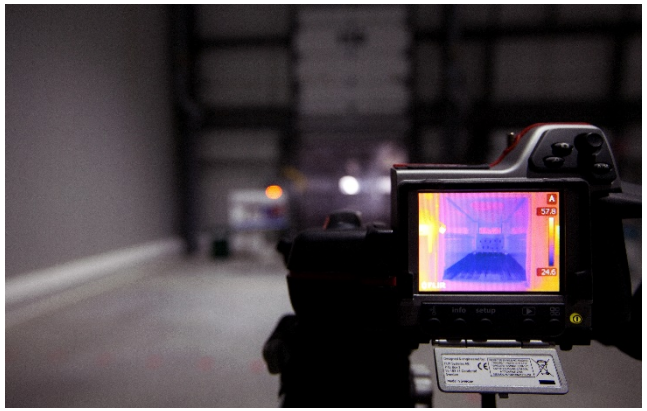
Data collection examples

1. Geographic coordinates
   a. Location
   b. Latitude
   c. Elevation
2. Internal and External conditions
   a. Temperature
   b. Relative humidity
3. Orientation
4. Building Enclosure
5. Insulation levels of walls, ceilings, and floors (Standard assumptions considered)
6. Window specification
   a. Dimensions
   b. Thermal conductivity (Standard assumptions considered)
   c. Solar Heat Gain Coefficient (SHGC) (Standard assumptions considered)
7. Infiltration and ventilation levels
8. Internal loads
9. Number of occupants / people density
10. Electronics, lighting and appliances.

Detailed Energy Audit – Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10





In-depth survey and monitoring

Collection for more accurate data

Confirm and compare operating and design data

Source: BEE India; https://images.app.goo.gl/8b1WHLTzNC6ipCfo8; https://images.app.goo.gl/JRtXpmToTkv3pnsx5; https://images.app.goo.gl/AwMbqGPkT8Dqxp776;

Detailed Energy Audit – Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

EA discussion with maintenance staff

- Are there any leaks in the roof?
- Are there moisture problems with the envelope of the building?
- Are there any general renovation needs for the envelope of the building? (rotten window frames, water leaks in seams of concrete plate, areas of insufficient insulation, etc.).
- Are there leaks in domestic water, waste water or heating systems?
- Are there cold or draughty spaces?
- Are any spaces too warm during the heating season?
- Are there any cooling needs?
- Are there frequent interruptions in water, heat or electricity supplies?
- Immediate repairs needed to domestic and waste water systems, heating and air-conditioning systems and electrical systems and how these needs should be taking into account when saving proposals are considered.

Source: http://www.brita-in-pubs.eu/toolbox/EA_files/EA_Quide_Axovaatio_ENG_RUS.pdf;

Detailed Energy Audit – Audit Phase

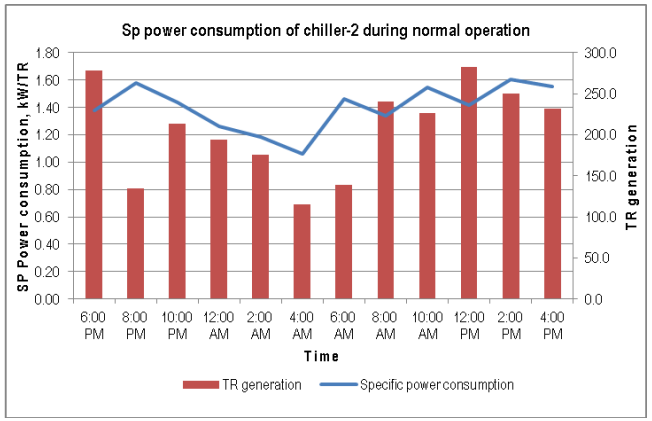
Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Data survey and monitoring example

Design details of chillers		
Description	**Unit**	**Chiller – 1,2 &3**
Type		Air cooled Semi Hermetic screw
Model		FOCS2/CA3602
Make of compressor		Bitzer
No of compressor in each chiller	Nos.	2
Refrigerant		R134A
Type of Evaporator		Shell & Tube - Dx
Make of Evaporator		Climaveneta
Evaporator water flow	m^3/h	93
Entering water temperature (EWT)	^0C	15
Leaving water temperature (LWT)	^0C	7
Differential Temperature	^0C	8
Air cooled condenser		
Number of fans per chiller	Nos.	16
Input power of condenser fans, each	kW	2
Max. Ambient temperature	0C	36
Cooling Capacity	TR	246
Power input to chiller compressor	kW	240.7
Max. Input power including condenser fans	kW/TR	272.7
Specific Energy Consumption	kW/TR	1.11kW/TR

Detailed Energy Audit – Audit Phase

- Step 1
- Step 2
- Step 3
- Step 4
- Step 5
- Step 6
- Step 7
- Step 8
- Step 9
- Step 10



- Power monitoring
- Load variation trends
- Efficiency Performance assessment and trials

Detailed trials and Experiments for energy intensive areas

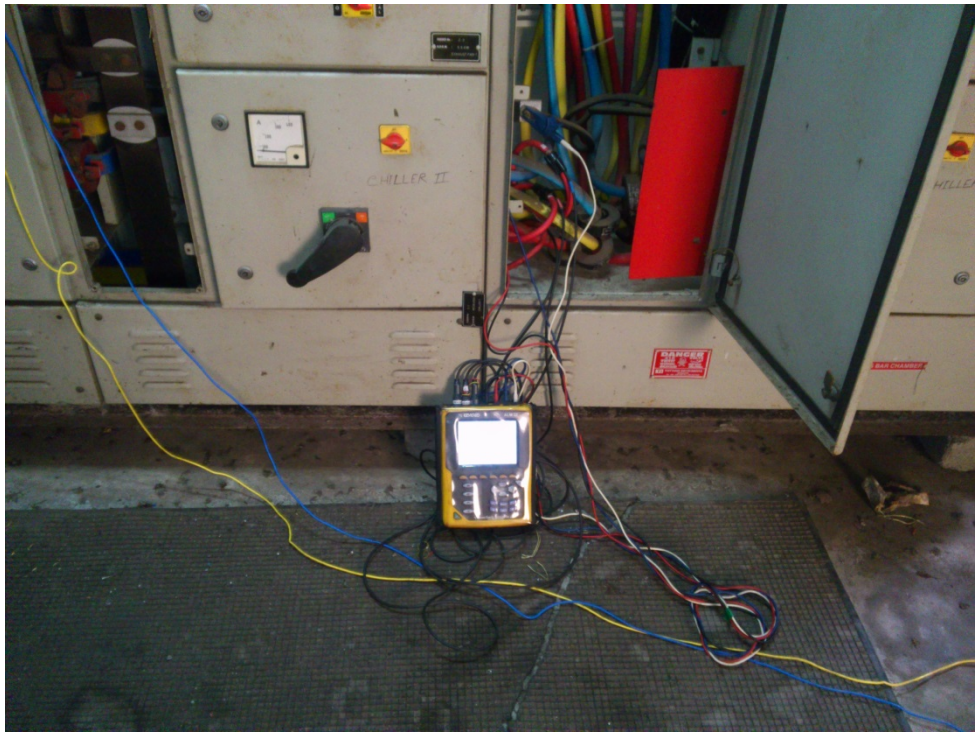
Source: BEE India; T E R I. 2013 [Project Report No. 2013IB05];

Detailed Energy Audit – Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Measurements

Instantaneous power measurements carried out with portable load analyser for all the motors



Source: BEE India; T E R I. 2013 [Project Report No. 2013IB05];

Detailed Energy Audit – Audit Phase

- Step 1
- Step 2
- Step 3
- Step 4
- Step 5
- Step 6
- Step 7
- Step 8
- Step 9
- Step 10

Measurement using Ultrasonic flow meter on a chilled water line

Source: BEE India; T E R I. 2013 [Project Report No. 2013IB05];

Detailed Energy Audit – Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

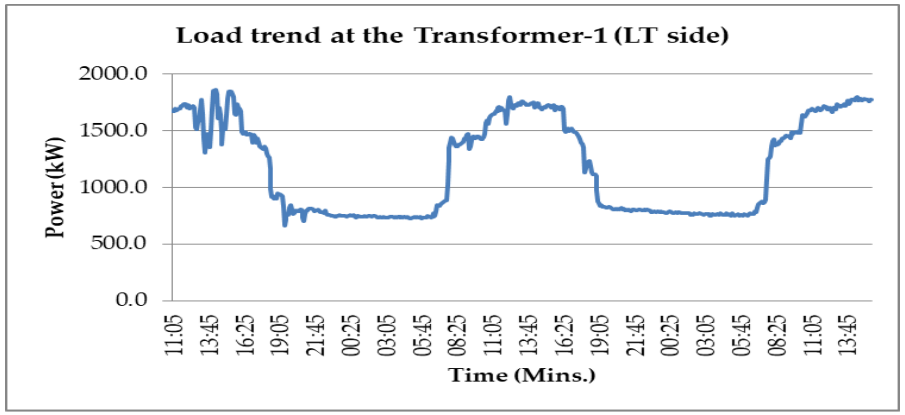
Trials and experiments - examples

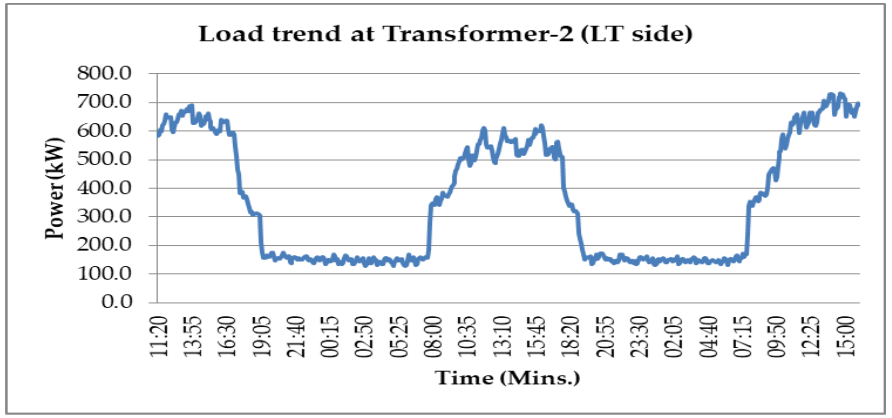
Transformer loading operational trials									
Parameter Description	Unit	Existing scenario				Proposed scenario			
		Trafo-1		Trafo-2		Trafo-1		Trafo-2	
		Day time	Night time	Day time	Night time	Day time	Night time	Day time	Night time
Rated capacity	kVA	3150	3150	3150	3150	3150	3150	3150	3150
No load losses	kW	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Load losses	kW	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
BEP	%	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9
Avg load	kVA	1616	770	508	154	1062	462	1062	462
Peak load	kVA	1854	866	641	216	1248	541	1248	541
% Loading of trafo	%	58.9	27.5	20.4	6.9	39.6	17.2	39.6	17.2
No load losses	kW	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Daily Load losses	kW	8.8	2.0	1.0	0.1	3.9	0.7	3.9	0.7
Total losses	kWh	156	74	62	52	97	59	97	59
Total losses	kWh/day	230		113		156		156	
Total losses	kWh/day	344				313			

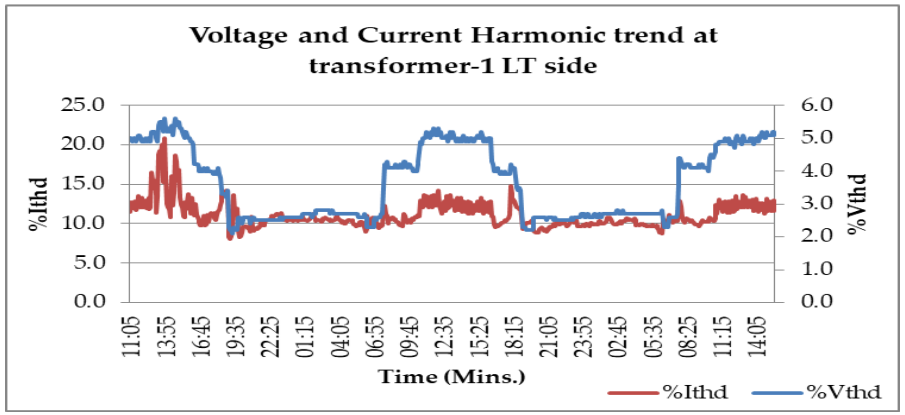
Detailed Energy Audit – Audit Phase

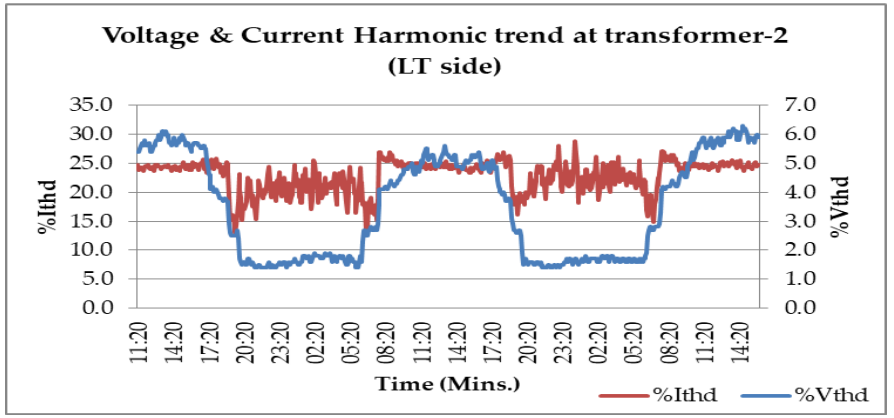
Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Trials and experiments - examples









Detailed Energy Audit – Audit Phase

- Step 1
- Step 2
- Step 3
- Step 4
- Step 5
- Step 6
- Step 7
- Step 8
- Step 9
- Step 10

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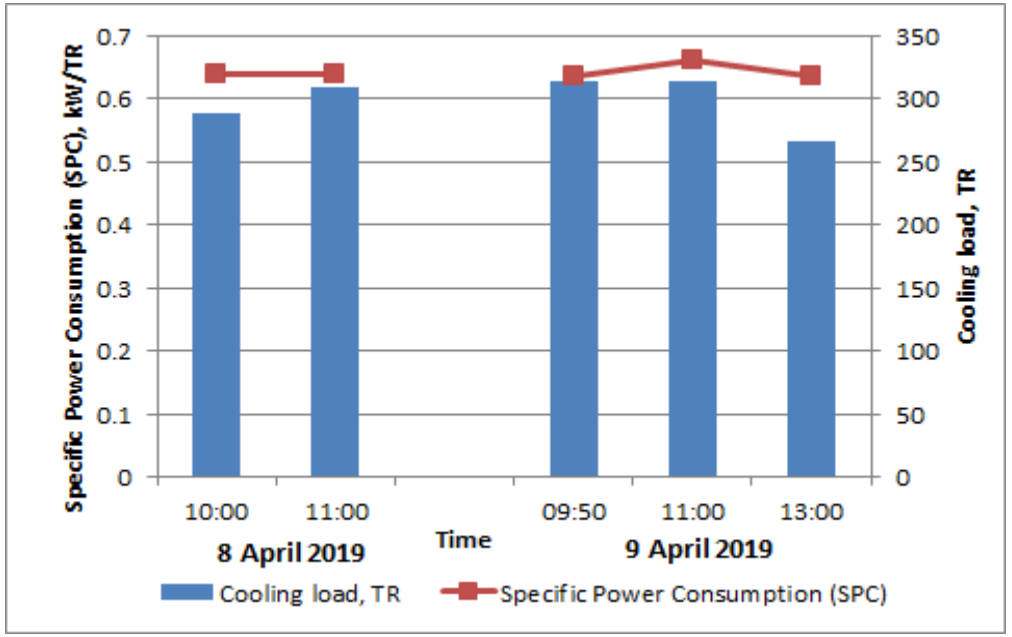
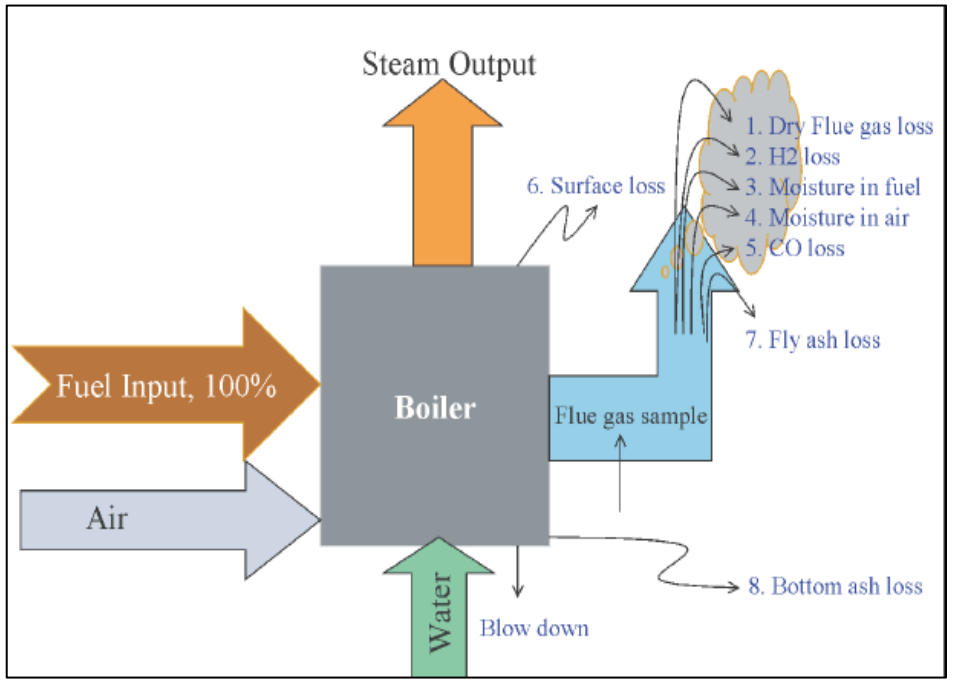
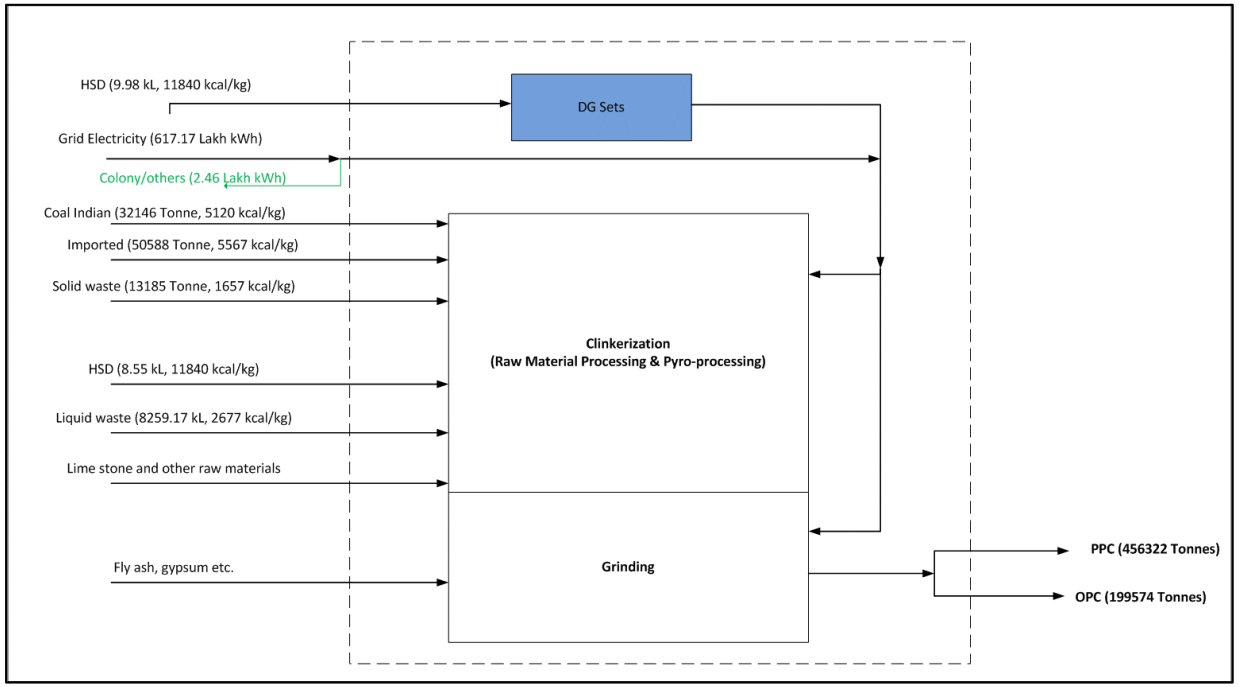


Parameters	Unit	Secondary pump 4 no's (1R/3S)					
		Rated	Operating				
			30 Hz	35 Hz	40 Hz	45 Hz	50 Hz
Make		Grundfos					
Type		NB100-250/245					
Flow	m3/h	160	70.6	82	91.1	101.2333	100.7
Total Head	m	16	6	8	11.5	14.5	17.5
Hydraulic power	kW	6.976	1.15	1.79	2.85	3.99	4.80
Motor power	kW	11	2.6	4.2	6.3	8.6	11.3
% motor loading	%		23.64	38.18	57.27	78.18	102.73
Motor efficiency		88.4 %					
Pump efficiency	%	71.74	50.22	48.15	51.26	52.61	48.07
Overall efficiency	%	63.42	44.40	42.56	45.32	46.51	42.50

Detailed Energy Audit – Audit Phase

- Step 1
- Step 2
- Step 3
- Step 4
- Step 5
- Step 6
- Step 7
- Step 8
- Step 9
- Step 10





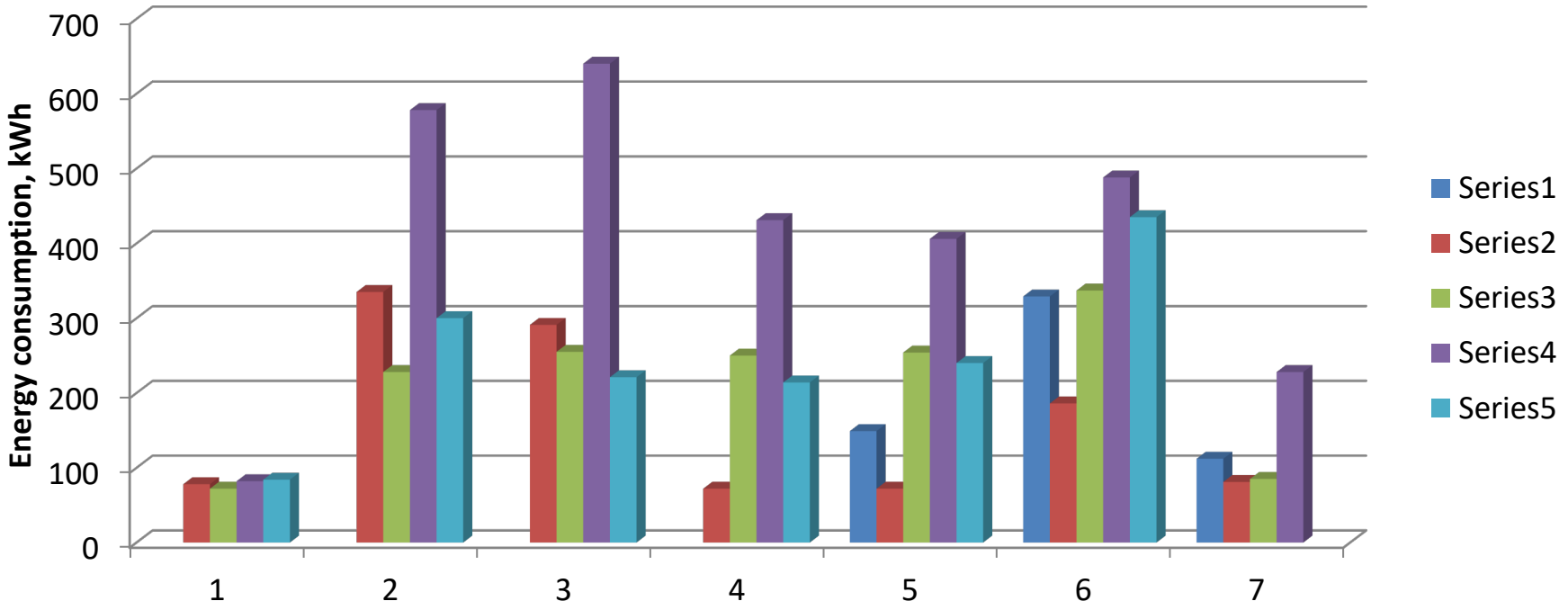
Analysis of energy use – Energy and Material balance, waste analysis

Source: BEE India;

Detailed Energy Audit – Audit Phase

- Step 1
- Step 2
- Step 3
- Step 4
- Step 5
- Step 6
- Step 7
- Step 8
- Step 9
- Step 10

Analysis of energy use examples for buildings



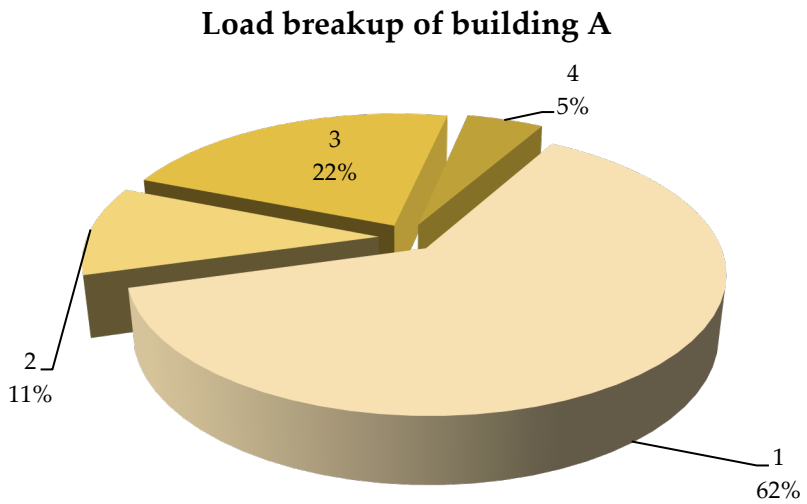
Note: Graph is only for example reference. Values does not represent actual value.

Detailed Energy Audit – Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Analysis of energy use examples for buildings

Load break-up of the building		
Description	Measured load, kW	
	Working day	Weekend day (Sunday)
Utility MCC-4	203.6	160.0
AREA -II	120.5	60.0
PMCC-2	507.7	200.0
PMCC-1	179.1	70.0
AREA –I	211.8	35.0
Chiller-1	178.6	175.0
Chiller-2	188.3	0.0
AREA- III	533.2	150.0
VRF unit	166.7	0.0
Total	2289.5	850.0

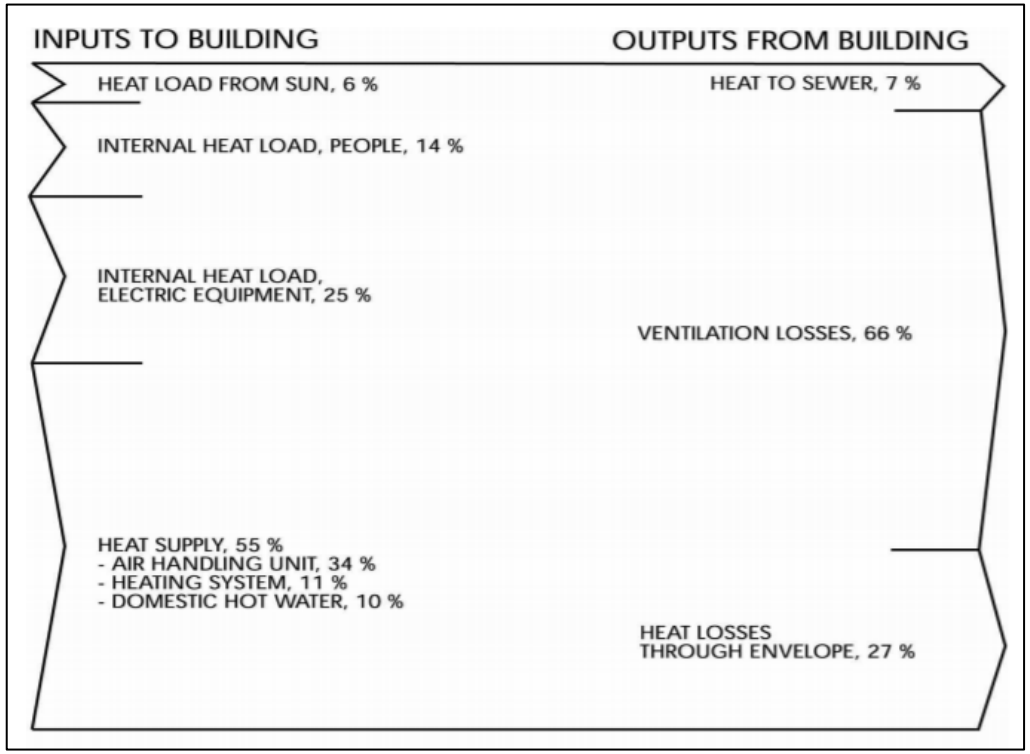


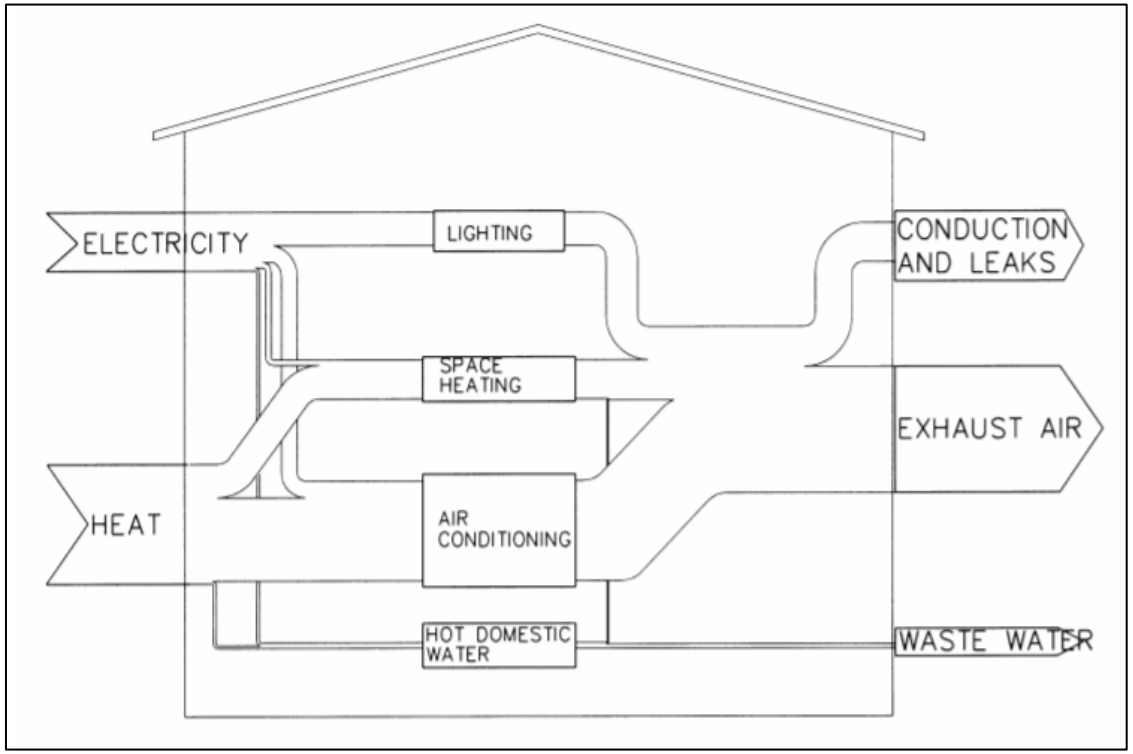
Source: BEE India;

Detailed Energy Audit – Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Example for energy balance for buildings





Source: http://www.brita-in-pubs.eu/toolbox/EA_files/EA_Quide_Axovaatio_ENG_RUS.pdf;

Detailed Energy Audit – Audit Phase

- Step 1
- Step 2
- Step 3
- Step 4
- Step 5
- Step 6
- Step 7
- Step 8
- Step 9
- Step 10

S.No	Energy Conservation Measures
Electrical Systems	
1	Parallel operation of Transformer-1 & 2
2	Install capacitor banks near chillers
Refrigeration and Air Conditioning systems	
2	Switch of primary chilled water pump
3	Replace process chilled water pump with optimum sized pump
4	Bypass VFDs of AHUVFM01, AHU 521, AHUVFM6, AHUVFM5, AHU516, AHU511, CSU01
Fans blowers and Vacuum pumps	
6	Avoid fresh air inclusion at the suction of the scrubber blower for Scrubber 35, 37,38, 39, Fume exhaust 3,4,7,9
7	Switch off Scrubber 27 B blower which is installed improperly
Compressed air system	
8	Replace S 16 air compressor with S 14 air compressor
Lighting	
9	Replace the existing 2 x 36 W T8 FTLs lamps with energy efficient 2 x 16 W T8 LED tube lights

Consolidate measures

Brainstorm

Contact vendors/ suppliers/technology providers

Identify and develop energy conservation opportunities

Source: BEE India; https://images.app.goo.gl/tndVf5Y6w8sw7hpv8; https://images.app.goo.gl/mEUhN4TTRbUvp5GV9;

Detailed Energy Audit – Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Type of Recommendations	No. of Recommendations	Annual Saving Potential, Rs. Lakh	Cost of Implementation, Rs. Lakh	Payback Period, Years
Short term investment, payback less than I Year	10	20.12	4.98	0.2
Medium investment, payback between 1- 3 years	5	10.06	20.7	2.1
Long investment, payback more than 3 years	2	11.57	61.62	5.3
Total	14	**41.75**	**87.30**	**2.1**

$$Cost\ savings = Energy\ savings \times Per\ unit\ Energy\ cost$$

Cost benefit analysis

Source: BEE India; https://images.app.goo.gl/wTPuN3aAJEzznYx86;

Detailed Energy Audit – Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Cost benefit analysis example – Electrical systems EC measures

S.No	Energy Conservation Measures	Annual Energy Savings Potential	Annual energy cost Savings,	Investment, Cost	Simple payback period
		Electricity, Lakh kWh	Value, Rs Lakh	Rs Lakh	Years
1	Parallel operation of Transformer-1 & 2	0.11	0.96	Nil	Immediate
2	Install capacitor banks near chillers	0.04	0.34	Nil	Immediate
3	Provide additional run of cable to Air compressor-2 and Chiller secondary pumps panel board	0.06	0.48	1	2.1
4	Install Active filter at different load centres	0.40	3.43	24	7.0

Detailed Energy Audit – Audit Phase

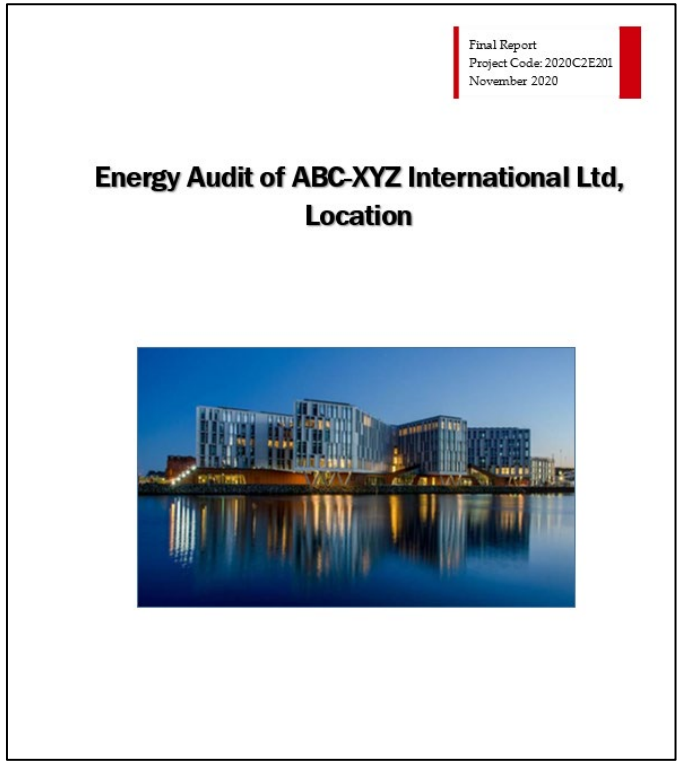
Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

Cost benefit analysis example – HVAC EC measures

S.No	Energy Conservation Measures	Annual Energy Savings Potential	Annual energy cost Savings,	Investment, Cost	Simple payback period
		Electricity, Lakh kWh	Value, Rs Lakh	Rs Lakh	Years
1	Switch off primary chilled water pump	1.10	9.34	Nil	Immediate
2	Replace process chilled water pump with optimum sized pump	0.17	1.43	1.5	1.05
3	Bypass VFDs of AHUVFM01, AHU 521, AHUVFM6, AHUVFM5, AHU516, AHU511, CSU01	0.02	0.20	Nil	Immediate
4	Avoid leakage of cold supply air via parallel connected stand-by systems for S16/TF/VAU 15A ,B and S16/TF/VAU13A,B	0.32	2.70	Minimal	Immediate
5	Technology upgradation to Electronically Commutated (EC) fan motors for the AHUs	0.96	8.14	37.62	4.6

Detailed Energy Audit – Audit Phase

- Step 1
- Step 2
- Step 3
- Step 4
- Step 5
- Step 6
- Step 7
- Step 8
- Step 9
- Step 10



Reporting and presentation to the top management

Source: BEE India; https://images.app.goo.gl/wTPuN3aAJEzznYx86; https://images.app.goo.gl/TXswSTaHbZKuAvQ57;

Post Audit Phase

Detailed Energy Audit

Detailed Energy Audit – Post Audit Phase

Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10

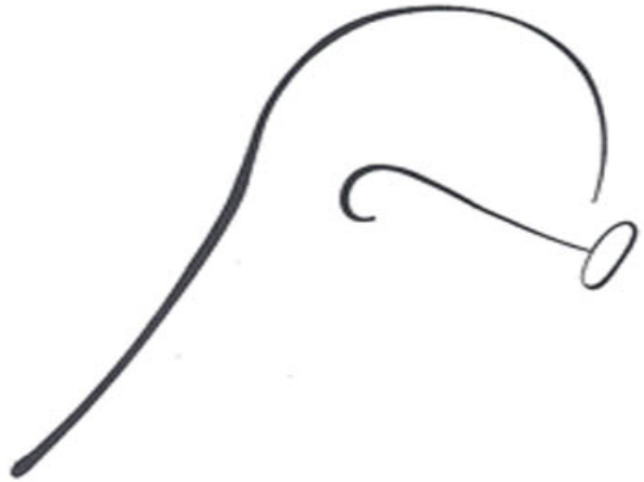
Assist in Implementation

Follow up

Periodic review

Implementation and Follow-up

Source: BEE India;



Be the change you want to see in the world

Thank You

Email: rradu@dtu.dk

List of references used

Slide: Building types. Picture references link

- Residential: https://images.app.goo.gl/wTyoGqCzZFiJNtYC9
- Educational: https://images.app.goo.gl/Pw641u3w7ckAjYZ17
- Healthcare: https://images.app.goo.gl/tgke3QWJXQSi8SSU9
- Business: https://images.app.goo.gl/Fq5dFSbK3B3Rd7p1A
- Industrial: https://images.app.goo.gl/MtTxPfTbvji1jqWS9
- Storage: https://images.app.goo.gl/3yDckhpoW5835ZYi9