ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE MATERIAL

COURSE NAME: ENERGY AUDIT

UNIT 1
ENERGY SOURCES

Energy consuming:

Energy consumption refers to ALL the energy used to perform an action, manufacture something or simply inhabit a building.

Here are a few examples:

In a **factory**, total energy consumption can be measured by looking at how much energy a production process consumes, for example, by making car parts. This will include water, electricity, gas… any energy source needed to transform the raw material into the final product

In a **household**, energy consumption includes electricity, gas, water, and any other energy used to live comfortably.

The energy consumption of **transportation** includes how much diesel or gasoline vehicles consume to run.

It is essential to understand that **energy consumption does not necessarily come from a single energy source**. Indeed, it is a common misconception to think that **to save energy you have to save electricity** whereas it could be a totally different energy source that has the greatest impact on a certain process.
Looking closely at the definition of energy consumption, it means that **the entire production process must be evaluated**. If you are part of a value-added process such as industrial metallurgy (like TACSA, for instance) the process does not end when the final product is manufactured. Indeed, if your shipping fleet brings them to the customer, the fuel for this delivery fleet is also part of your energy consumption

Energy reserves:

The most commonly used terms are “reserves” and “resources.” "Reserves" represent that portion of demonstrated resources that can be recovered economically with the application of extraction technology available currently or in the foreseeable future. Reserves include only recoverable energy.

Energy policies:

Energy policy is **the scheme in which the government (or any organization) addresses issues related to energy growth and usage including energy production, distribution, and consumption**.

Energy conservation schemes:

SCHEMES TO PROMOTE ENERGY CONSERVATION AND ENERGY EFFICIENCY

(i) Standards and Labeling

The Bureau initiated the Standards and Labeling programme for equipment and appliances in 2006 to provide the consumer an informed choice about the energy saving and thereby the cost saving potential of the relevant marketed product. The scheme is invoked for 19 equipment/appliances, i.e. Room Air Conditioners, Fluorescent Tube Lights, Frost Free Refrigerators, Distribution Transformers, Induction Motors, Direct Cool Refrigerator, electric storage type geyser, Ceiling fans, Color TVs, Agricultural pump sets, LPG stoves, Washing machine, Laptops, ballast, floor standing ACs, office automation products, Diesel Generating sets & Diesel operating pumpsets of which the first 4 products have been notified under mandatory labeling from 7th January, 2010. The other appliances are presently under voluntary labeling phase. The energy efficiency labeling programs under BEE are intended to reduce the energy consumption of appliance without diminishing the services it provides to consumers. Further, the standards and label for refrigerators and air-conditioners have been periodically made more stringent. As a result, the least-efficient products are removed from the market and more efficient products are introduced. The Corporate Average Fuel Consumption Standards (CAFC) for passenger cars has been notified on 30th January, 2014. The most

recent additions to the list of labeled products are Diesel Pumpsets& Diesel Generating Set.

During the XII plan, Standards and Labelling programme will target at least 3 more new equipments / appliances including up-gradation of energy performance standards for equipments/ appliances covered during XI Plan.

(ii) Energy Conservation Building Codes (ECBC)

The Energy Conservation Building Code (ECBC) was developed by Govt. of India for new commercial buildings on 27th May 2007. ECBC sets minimum energy standards for new commercial buildings having a connected load of 100kW or contract demand of 120 KVA and above. While the Central Government has powers under the EC Act 2001, the state governments have the flexibility to modify the code to suit local or regional needs and notify them. Currently eight States and Union Territories (Rajasthan, Odisha, UT of Puducherry, Uttrakhand, Punjab, Karnataka, Andhra Pradesh & Telangana) notified and adopted the code for their states. In order to promote a market pull for energy efficient buildings, Bureau of Energy Efficiency developed a voluntary Star Rating Programme for buildings which is based on the actual performance of a building, in terms of energy usage in the building over its area expressed in kWh/sq. m/year. Currently, Voluntary Star Labelling programme for 4 categories of buildings (day use office buildings/BPOs/Shopping malls/Hospitals) has been developed and put in public domain.

(iii) Demand Side Management (DSM) Scheme

(a) Agriculture DSM

In order to tap the energy saving potential, Agriculture Demand Side Management (AgDSM) program was initiated in XI plan by Bureau of Energy Efficiency with an objective to induce energy efficiency in agriculture sector by creating market based framework for implementation of few pilot projects and create awareness among end users & other stakeholders for adoption of energy efficient pumpsets (EEPS). Major milestone achievements of the scheme during XI plan were:

- 11 Detailed Project Reports (DPRs) have been prepared in 8 states for 11DISCOMs covering 20,750 pumpsets connected on 87 feeders. Average 40% (96 MU) energy saving potential assessed.
- One pilot project in Solapur, Maharashtra is being implemented and reflects savings of 6.1 MU by efficiency up gradation of 2209pumpsets.Monitoring & Verification methodology have been prepared and is under implementation for realizing energy savings in Solapur pilot project.
- Punjab & Haryana mandated the use of BEE star rated pumpsets for every new agricultural connection in the state. 67843 and 1599 pumps have been reported installed under the regulation in the state of Haryana and Punjab respectively.

During the XII plan, realizing the vast energy saving potential in the sector, BEE intends to continue the programme with an objective to build up the process of acceleration of sustainable energy efficiency in the plan through following interventions:

- Regulatory mechanism to mandate the use of BEE star labeled pump sets for new connections
- Facilitate implementation of DPRs and setting up monitoring & verification protocol
- Technical assistance and capacity development of all stakeholders

(b) Municipal DSM

Identifying the immense energy saving potential in municipal sector, BEE initiated Municipal Demand Side Management (MuDSM) during XI plan. The basic objective of the project was to improve the overall energy efficiency of the ULBs, which could lead to substantial savings in the electricity consumption, thereby resulting in cost reduction/savings for the ULBs. The major achievements in the XI plan period are as follows.

- Situational survey was conducted in 175 ULBs across the country.

- In 134 ULBs, Bankable DPRs were prepared after taking up Investment Grade Energy Audit (IGEA). The overall potential saving of 120 MW is estimated as part of avoided generation capacity through energy efficiency proje`cts in 134 ULBs.
- MuDSM web portal was developed under the programme. The portal consists of DPRs and knowledge materials developed under the programme.

Implementation of the project at the ground level is highly necessary which will create a market transformation among technology provider, implementing partners, financial institutions etc. In view of these facts, it is proposed that implementation of demo projects in 15 ULBs will be undertaken on pilot basis during XII plan. In addition, technical support will be provided to the ULBs by appointing technical experts to selected ULBs.

(c) Capacity Building of DISCOMS

The objective of the programme is capacity building of DISCOMs for carrying out load management programme, energy conservation programme, development of DSM action plan and implementation of DSM activities in their respective areas. This programme would help the DISCOMs for reducing peak electricity demand so that they can delay building further capacity.

(d) Energy Efficiency in Small and Medium Enterprises (SMEs) sector

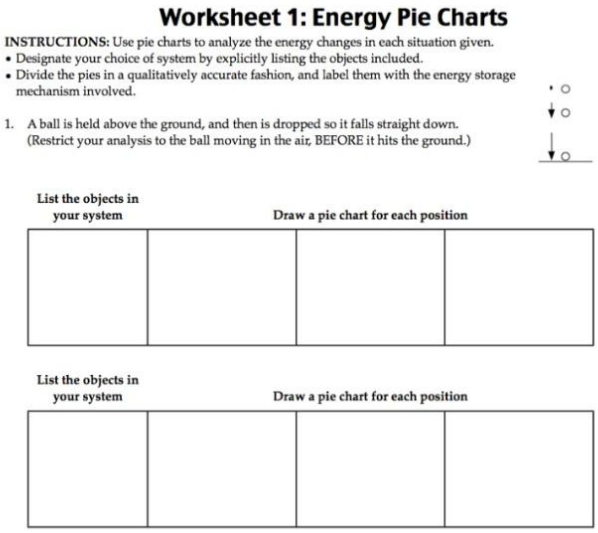
To encourage the energy efficient technologies and operational practices in SME sectors in India, BEE has initiated the energy efficiency interventions in selected 25 SMEs clusters during the XI plan. A study was conducted to assess energy use and technology gap at unit level, development of the cluster specific energy efficiency manuals, preparation of Detailed Project Reports (DPRs) on energy efficient technologies and capacity building and knowledge enhancement of man-force involved in SMEs. During the XII plan, implementations of 100 technology demonstration projects in 5 SME sectors are envisaged to facilitate large scale application.

Industrial energy use:

Industrial energy use, is **what allows industries to extract resources and produce goods**. Industrial energy use should not be confused with commercial energy use; while both are businesses, commercial means engaging in commerce, industrial means producing goods, usually from raw materials.

Energy Pie Charts

The stage is set. We started **building the energy transfer model** (ETM), and we've **talked about the flavors of energy**. We are ready for a new representation to help us start thinking about energy storage in a system. In a day or two, we'll be using **energy bar charts**, but first, we'll get used to thinking about energy storage with a simpler, stepping stone diagram.



Worksheet 1: Energy Pie Charts

INSTRUCTIONS: Use pie charts to analyze the energy changes in each situation given.
- Designate your choice of system by explicitly listing the objects included.
- Divide the pies in a qualitatively accurate fashion, and label them with the energy storage mechanism involved.

1. A ball is held above the ground, and then is dropped so it falls straight down. (Restrict your analysis to the ball moving in the air, BEFORE it hits the ground.)

List the objects in your system	Draw a pie chart for each position		

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Sankey diagram – a definition:

What is a Sankey diagram?

Sankey diagrams feature directed arrows that have a width proportional to the flow quantity visualized: if a flow is twice as wide it represents double the quantity. Flow diagrams can show e.g. energy, materials, water or costs.

Within a Sankey chart the directed flow is always drawn between at least two nodes (processes). Thus it shows not only values but also information about the structure and distribution of the defined system. So they are a great alternative to common flow or bar & pie charts.

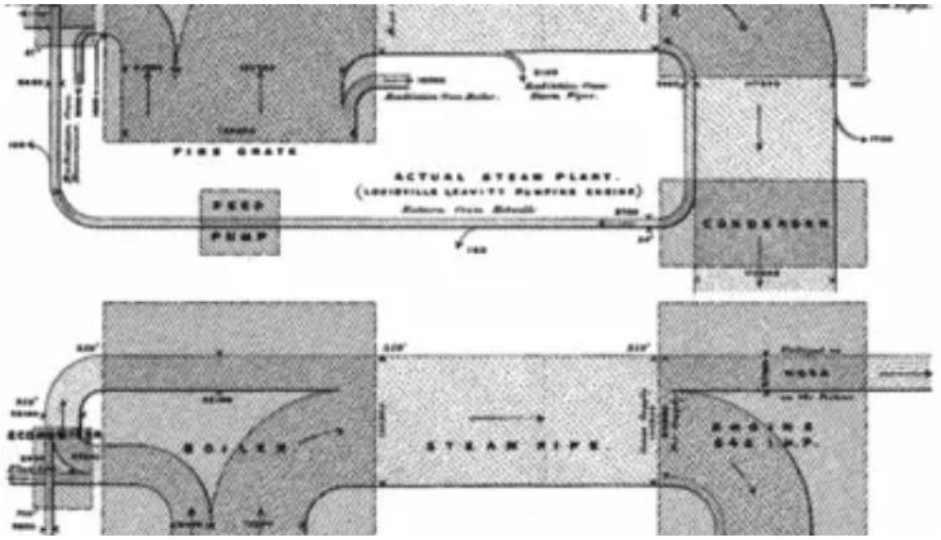
Areas of application

They are gaining popularity in energy management, facility management, process engineering and process control and many other kinds of data visualization (Energy, material & supply chain management or business & marketing analysis).

Benefits of Sankey diagrams

In comparison to a conventional bar or pie chart and even a flow chart, they are more suitable for visualizing the energy balance or material streams.

Sankey charts draw the attention to the largest and most significant entries within a system. Additionally, through the visualization data inconsistencies can be detected, such as measurement and transmission errors.


FIRE GRATE
ACTUAL STEAM PLANT.
FEED
PUMP
CONDENSER
BOILER
STEAM PIPE

UNIT 2

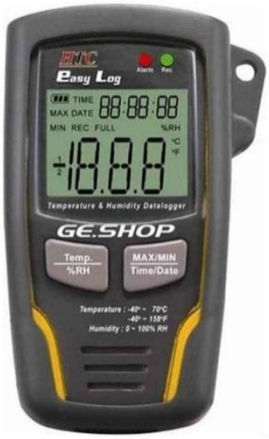
ENERGY EFFICIENT INSTRUMENTS

Digital Energy Meter:

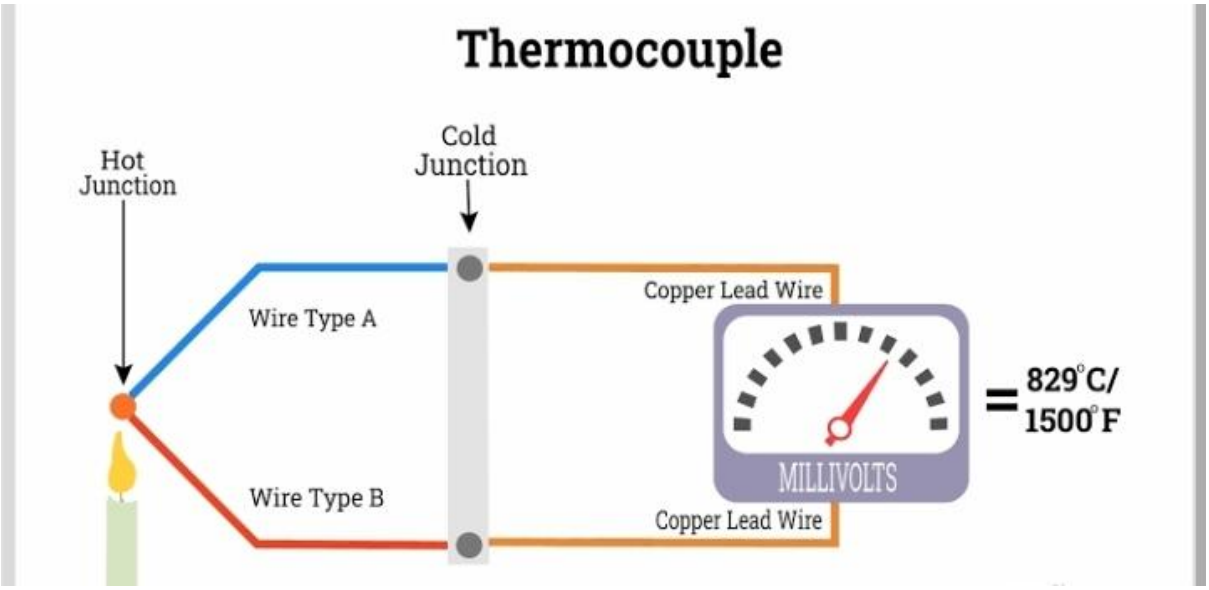
Digital energy meters also called advanced meters or smart meters, are **intelligent devices that automatically record the user consumption of water and electricity**. After the data is collected, digital meters electronically report all the gathered information to the utility company at regular intervals.

Data loggers:

A data logger is an electronic device that records data over time or about location either with a built-in instrument or sensor or via external instruments and sensors. Increasingly, but not entirely, they are based on a digital processor, and called digital data loggers.



Thermo couples:



A thermocouple, also known as a "thermoelectrical thermometer", is an electrical device consisting of two dissimilar electrical conductors forming an electrical junction.

Pyranometer:

Lux meters:

A lux meter works by using a photo cell to capture light. The meter then converts this light to an electrical current, and measuring this current allows the device to calculate the lux value of the light it captured.

Tong testers:

Tong tester or clamp meter basically works on the principle of **mutual inductance** . The same principle on which a transformer works. The clip or clamp or moving part of meter has a magnet in it which act as a magnetic core as in transformer. Over which there is a coil wounded, which acts as a secondary coil.

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 O_2 and CO_2 measurement.

Power analyzers:

The Working Principles of Power Analyzers

Power analyzers can be used to measure the flow of energy in either alternating current (AC) or direct current (DC) systems – with distinct considerations for measuring AC circuits.

The determination of an electrical signal's True RMS time period underlines each of the subsequent calculations performed by the measuring instrument. This is complicated by AC measurements, where root mean square is typically expressed as an equivalent DC value. To accurately determine the True RMS of an AC waveform, an average must be calculated across the cycle of the AC frequency. This is defined as the fundamental frequency of the circuit. Power analyzers can digitally detect frequency cycles to provide reliable RMS periods during power conversion.

A power analyzer must also detect the voltage and current of the system. Typical systems directly acquire individual voltages using voltage dividers, while a transformer is usually required to measure the current. This may comprise a coil that measures the electrical field of a wire carrying a current, or a flux gate current transducer.

Power factor correction (PFC) **aims to improve power factor, and therefore power quality**. It reduces the load on the electrical distribution system, increases energy efficiency and reduces electricity costs. It also decreases the likelihood of instability and failure of equipment.

Electric lighting :

Types of lighting:

Proper lighting can have a significant impact on how you feel in a space, and each space may call for a variety of different lighting requirements. A good lighting setup combines different types of lighting to create a welcoming space where you can easily work or relax. There are three basic types of lighting you should layer in a room in order to accomplish this:

- Ambient or general lighting
- Accent lighting
- Task lighting

UNIT 3
ECONOMIC ASPECTS

Costing Techniques:

Low- and no-cost measures typically are easy to implement, but getting funding for the capital projects can be more difficult. To make the business case for implementation and to determine if an identified energy-conservation measure is financially feasible, managers must perform an economic analysis.

This analysis should include:

- ✓ energy cost savings the measure will deliver, including consumption and demand savings
- ✓ the cost to implement the measure
- ✓ additional maintenance costs the measure will require.

With the needed information to determine total savings and the total cost to implement the measure, managers can calculate the payback associated with the energy-conservation task.

In general, managers first should implement projects with the shortest payback period. Managers can base the approach for implementing projects with longer payback periods on the organization's economic approach and energy goals. These goals for an organization that is simply leasing a building for five years — a commercial office building, for example — are likely to be different from those of an organization that owns a building — a school district, for example. Aligning energy goals with overall organizational goals is essential to performing a successful energy audit.

Once managers have implemented the projects, the final step of an energy audit is measuring and monitoring the facility's operations and energy use to prove the projects have produced results. Managers can track progress in this area by reviewing utility bills and tracking savings from the energy-conservation measures.

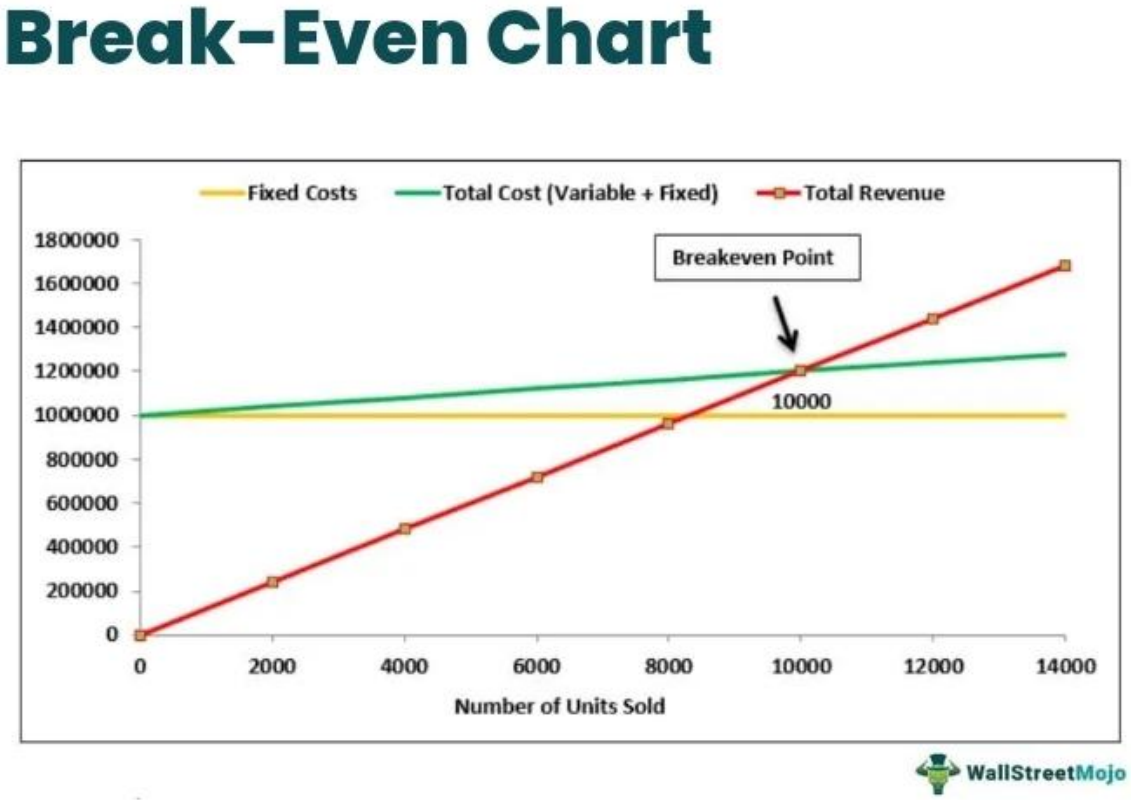
This final step is likely to further emphasize the economic benefits of performing an energy audit because it will show the real savings associated with the audit and the opportunities it uncovered. Achieving energy-conservation goals will enable managers to build on their successes and set new energy goals for the future.

Break-even charts:

Break-even chart shows the relationship between cost and sales and indicates profit and loss on different quantity on the chart for analysis where the horizontal line shows the sales quantity and the vertical line shows the total costs and total revenue and at the intersection point it is breakeven point which indicates no profit and no loss at given quantity.

On the vertical axis, the breakeven chart plots the revenue, variable cost, and the fixed costs of the company, and on the horizontal axis, the volume is being plotted. The chart helps in portraying the company’s ability to earn a profit with the present cost structure.

The following example of the break-even chart provides an outline of the most common type of break-even chart present. Each of the examples of the breakeven chart states the topic, relevant reasons, and additional comments wherever required.



Note that it is customary to take cash flows during a year at the end of the year, or EOY (end-of-year). There are certain cash flows for which this is not appropriate and must be handled differently. The most common would be rent, which is normally taken at the beginning of a cash period. There are other pre-paid flows which are handled similarly.

For example, consider a truck that is going to be purchased for $55,000. It will cost $9,500 each year to operate including fuel and maintenance. It will need to have its engine rebuilt in 6 years for a cost of $22,000 and it will be sold at year 9 for $6,000. Here is the cash flow diagram:

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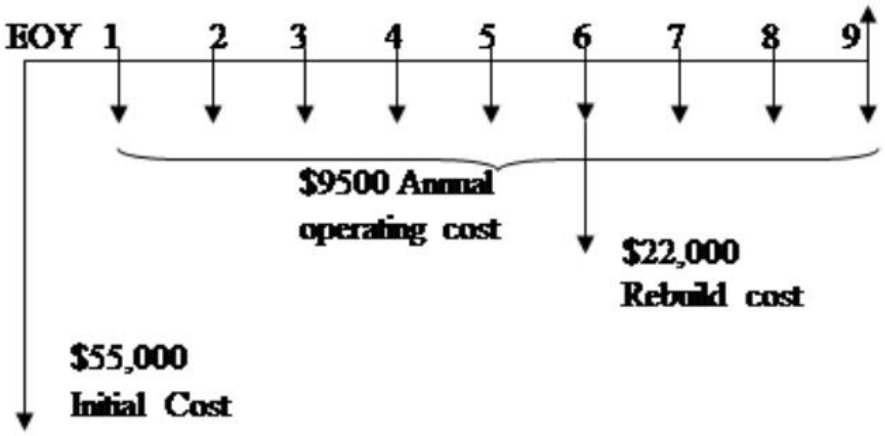

Note that the initial cost, the purchase price, is recorded at the beginning of Year 1, sometimes referred to as end-of-year 0, or EOY 0. Also, operating and maintenance costs actually will occur during a year, but they are recorded at EOY, and so forth.

Cost optimization:

The U.S.-India Joint Center for Building Energy Research and Development (CBERD) conducts energy efficiency research and development (R&D) with a focus on developing Triple Bottom Line (TBL) life cycle justifications (economic, environmental and human) for building decision makers critical to overcome first-least-cost decision making patterns that prevent investments in high performance, energy efficient building solutions.

The research is focused on the identification of economic, environmental and human benefits of energy-efficient technologies and systems for customizable cost benefit calculations including simple payback and net present value.