Chapter 2

Idea and Theory about Research

The idea and theory about research are clarified here for using in the following.

2.1 Term of Reference (TOR) of the Energy Audit Report

The TOR: Term of Reference for the contract of the energy audit report between the Department of the Energy Development and Promotion and the Energy Conservation Center of Thailand are described here [7,pp1-6.].

2.1.1 Introduction

Survey and audit the characteristic of energy utilization. Analyze the detail of the potential of the energy conservation in the state building for implementing.

2.1.2 **Survey and Audit the Characteristic of Energy Utilization** (All suggested equipment for improvement must enclose the picture)

Electrical Power Supply System

- The Energy Consumption
- The Number and Capacity of Main Equipment

The examples of main equipment are transformer, control board, generator, capacitor, motor, and pump etc. Draw the load in the form of the single line diagram.

The required data are power (watt), voltage (volt), current (ampere), and power factor. The data include size and status of the main line and circuit breaker.

Split Type and Window Type of Air Conditioning System

- The Lay out Drawing of Existing Air Conditioner and Thermostat
- The Data from Existing Air Conditioner and Thermostat for Efficiency Calculation.

The data are capacity (Btu), age (years), power (watt), voltage (volt), current (ampere), power factor, EER: Energy Efficiency Ratio (Btu/h/watt), capacity per area ($Btu/hr/m^2$)

Each capacity and age of air conditioner should be audited more than 3 sets. (There are 5 ranges of the age: more than 3-5 years, more than 5-6 years, more than 6-7 years, more than 7-8 years, and more than 8 years)

Central Unit Air Conditioning System

- The Lay out Drawing of the Existing Equipment

The examples of equipment are chiller, condenser water pump, cooling tower, pipe, and others. [8,pp33-37]

The data are capacity (Btu), age (years), power (watt), voltage (volt), current (ampere), power factor, COP: Co-efficient of Performance, and capacity per area ($Btu/hr/m^2$).

Lighting System

- The Lay out Drawing of the Existing Lighting System
- The Data from Lighting Equipment

The data of luminaries are material, reflector in luminaries, cover of luminaries, characteristic of lamp, accessories of luminaries e.g. ballast, maintenance condition, average illuminant (lux) on working plane, and capacity of lighting (watt/m^2) [9,pp50-52].

Thermal Transfer through Building Envelope

- The data for calculation of the Overall Thermal Transfer Value (OTTV) and Roof Thermal Transfer Value (RTTV) by using the approved software from the Department of the Energy Development and Promotion.

The data are picture, map with direction, characteristic with type and layer of opaque and transparent including insulation, area in each direction, and shading characteristic.

Heating System

- Lay out Drawing of Existing Heating System
- The Data of the Equipment and Machine

The examples equipment are boiler, steam equipment, hot water equipment, pipe, and others about energy utilization including the heat loss.

The data are fuel consumption, quantity of heat production, capacity of heat consumption, capacity of heat production, age of using, quantity/temperature/pressure of heating equipment, blow out heat and condensate system, characteristic of insulation/ piping system/heating equipment, efficiency of system or equipment, and maintenance condition.

2.1.3 Technical Analysis

Analyze the Electrical Power Supply System and Suggest the Measures

Analyze the Air Conditioning System and Suggest the Measures

- Replace the low Energy Efficiency Ratio air conditioner with the high Energy Efficiency Ratio air conditioner or improve the Coefficient of Performance in the case of central unit.
- Install the insulation on the top part of the building.
- Maintenance the existing air conditioner.
- Use the electronic thermostat with the appropriate temperature.
- Others

Analyze the Lighting System and Suggest the Measures

- Replace the existing lamp by the high efficiency lamp.
- Replace the magnetic ballast by the electronic ballast.

- Replace the non-reflector luminaries by the reflector luminaries. Improve the illumination to be more than 350 lux in the plane of room.

Analyze the Thermal Transfer through the Building Envelope and Suggest the Measures

- Install the insulation on the top part of the building.

- Attach the film, fin, or overhang to reduce the Overall Thermal Transfer Value and the Roof Thermal Transfer Value as the ministerial regulation [10,pp5-6]. Explain the reason if the measures cannot be implemented.

Analyze the Heating System and Suggest the Measures

- Improve the efficiency of system and equipment

Analyze the Important Index

- Calculate the important index of the heating system and the electrical system per area or bed of patient in the case of the hospital building depending on the characteristic of the building. The examples of the indices are Btu/m^2 for the air conditioning system, watt/m^2 for the lighting system, liter/man or liter/m^2 for water consumption

Analyze the Measures in the Economic View

- Calculate the cost of main equipment and accessories, labor cost, and miscellaneous cost such as in air conditioner of each set.

- Calculate the payback period.

- Calculate the Internal Rate of Return (%IRR)

2.1.4 Show the detail of implementation

Electrical Power Supply

- Show the lay out drawing the new system.
- Detail the technical installation.
- Show the specification of new equipment.
- Maintain or suggest for improving about safety.

Air Conditioning System

- Lay out the new system both air conditioner and electronic thermostat.
- Show the technical installation of FCU: Fan Coil Unit, CDU: Condensing Unit, refrigerant pipe, switch, size of circuit breaker, and main line.
- Show the specification of new equipment both air condition and electronic thermostat.

Lighting System

- Lay out the existing and new system. Show the maximum, minimum, and average illuminant (lux).
- Show the picture and method of the existing and new luminaries.

- Show the number and capacity (watt) of electronic ballast and method of installation.

- Show the specification of the new equipment.

Building Envelope

- Show the area of installation of the new insulation.

- Show the method of installation.

- Show the specification of the insulation.

2.2 Energy Audit

The successful definition, implement, and management of an industrial energy conservation program require a proper framework and baseline for identifying and evaluating energy conservation opportunities. Energy cannot be saved until it is known where and how it is being used and when and where its efficiency can be improved. In most cases, the establishment of this baseline requires a comprehensive and detailed survey of energy uses and losses: this survey is generally know as the *energy audit.* (The term "survey" is being used more and more in conjunction with national / macro level energy use studies and the term "audit" with site-specific analyses.) [11,p1-1]

This kind of activity is carried out primarily to identify energy saving potential of all sectors and then recommend practical steps in attaining such potential. Some companies, particularly industries, have been dealing with this activity through monitoring, measuring and calculating directly the operation parameters of the potential together with its feasibility analysis. [12,p20]

There are three steps to define the target and energy conservation plan after auditing [13,p8]

- Do the preliminary energy audit.
- Do the detailed energy audit.
- Define the target and energy conservation plan.

The Preliminary Energy Audit (PEA) is essentially a preliminary data gathering and analysis effort. It consists of two parts: the energy management audit, through which the auditor becomes acquainted with investment decision criteria as the energy conservation projects, and the technical energy audit. The technical part of the Preliminary Energy Audit uses only available data and is completed without sophisticated instrument. The Preliminary Energy Audit is conducted in a every short time frame (i.e., a day or a few days), during which the energy auditor relies on his experience to gather all relevant written, oral, or visual information that can lead to a quick diagnosis of the plant energy situation. The Preliminary Energy Audit focuses on

the identification of obvious sources of possible improvement in energy use. Examples of easily identified possibilities are missing insulation, steam and compressed air leaks, inoperative instrumentation, and equipment operating unnecessarily. The typical output of the Preliminary Energy Audit is a set of recommendations on immediate low-cost actions that can be taken and usually, a recommendations for a more extensive plant energy analysis -the detailed energy audit.

The Detailed Energy Audit (DEA), which must always be conducted after a PEA, is an instrumented survey followed by a detailed plant energy analysis. Sophisticated instrumentation is used to enable the energy auditor to compute energy efficiencies and balances during typical equipment operation. The actual tests performed and the instruments require depend on the type of facility under study and the objective, scope, and level of funding of the energy management program. Thus, a detailed energy audit can take as little as 1 man-week or as much as several man-years in a sophisticated plant, such as a petrochemical complex, where expected savings justify such an effort. Types of tests conducted during a detailed energy audit include combustion efficiency tests and measurement of temperatures and air flows of major fuel-using equipment, determination of power factor degradation caused by various pieces of electrical equipment, and testing of process systems for operation within specification.

After obtaining the test results, the energy auditor checks and validates them using preliminary computation and existing support materials (tables, chart, calculators , computers). Then , he uses the results to build energy and mass balances, first for each major piece of equipment tested and then for the plant as a whole. From such balances, he can determine how efficiently each piece of equipment is actually operating and whether there is room for energy cost reduction. Next, he analyzes the data, concentration on identifying costs and benefits of selected options (actions, investments) for each opportunity. In some cases, the energy auditor will be unable to recommend a specific investment because of its magnitude or the associated risk. In such a case, the auditor will recommend specific feasibility studies (e.g., boiler replacement, furnace modification, steam system replacement, process changes). The detailed energy audit stops at this point; its final output is a detailed report presenting the auditor's recommendations, together with their associated costs, benefits, and implementing characteristics (timing, impact on production). [11,pp1-2 - 1-3]

2.3 Approaches of Energy Management

In general, three kinds of approaches are possible for energy management: [14,p1.1.1]

- Product changes toward less energy intensive goods, product mix, or product composition.
- Equipment and process design improvements
- Instrumentation, control and process management improvements.

2.4 Energy Conservation in Buildings

Energy conservation inside the buildings means one of the following measures: [15,p9]

- Reduction of heat from the sunlight that enters the building.
- Efficient air – conditioning, including maintaining room temperature at an appropriate level.
- Use of energy – efficient construction materials and demonstration of qualities of such materials.
- Efficient use of light in the building.
- Use and installation of machinery, equipment, and materials that contribute to energy conservation in the building.
- Use of operation control system for machinery and equipment.
- Other measures for energy conservation as prescribed in the Ministerial Regulations.

2.5 Data Collection

Data means the information, which can be analyzed, concluded, and utilized. Data can be collected in the form of figure, word, and any media. Data is vital for the study or research because the credit of data leads to the credit of the research. Moreover the method of analysis depends on the data collection and the characteristic of the data.

There are two types of the data.

- The primary data means the data without the analysis.
- The secondary data means the data with the idea and analysis of the auditor.

The good point of the primary data is the conception of the auditor that what the defect and limit of the data are. However the primary data collection requires much time and money. On the other hand the good point of the secondary data is the fast grasping of idea from the data. Thus the trust of the secondary data depends on the source.

There are three methods of the data collection.

- The data record from the register is the method that uses the observation from the situation. So the requirement of the data is the configuration of the format of record.

- The data record from the survey can do by surveying from the sample or from the census. The method of survey may be the interview or questionnaire.

- The data record from the experiment is always used for the situation with many variables. The experiment gets rid of the result from the other factors. [16,pp271-274]

2.6 Energy Audit Report Presentation

The main idea of detailed energy audit report for controlled building is composed of ten parts. [17,pp13-15]

2.6.1 Introduction

General Data

- Building name
- Address
- Building type and age of building

- Number of room for hotel building, number of bed for hospital building, Area in square meter unit for other types of building
- Percent of using room in each month for hotel building, number of general patient and admit patient in each month for hospital building
- Area (total area, air conditioning area, and car park area)
- Energy consumption in each year (type, quantity, and price of fuel or quantity, price, and demand peak of electricity)
- Lay out of building
- Number of employee, operator, or worker
- Working time
- Name of energy responsible person
- Name of auditor

Energy Consumption

- Fuel consumption in last one year / quantity and condition of fuel consumption in main equipment / quantity and condition of fuel consumption in each department
- Electricity consumption in last one year / quantity and peak demand in each month in last one year / energy consumption of lighting system, air conditioning system, and other systems in each month

Energy Balance

- Energy balance of main equipment
- Energy balance of building

Comparison of energy consumption to ministerial regulation about the standard, principles, and method of energy conservation in controlled building

2.6.2 Detail of energy utilization in main equipment

Main Thermal Equipment

- Data of thermal equipment and data from auditing

Main Electrical Equipment

- Data of electrical equipment and data from auditing

2.6.3 Energy Conservation Opportunities Assessment

- Reduce the heat transfer through the building envelope
- Use the air conditioning system efficiently and set the appropriate temperature
- Use the energy conservation material for building construction
- Use the lighting efficiently
- Install the equipment for energy conservation
- Use the control system for machine and equipment

- Improve the efficiency of equipment such as the heat loss protection, use the high efficiency equipment, reuse the energy from the blow out energy, and improve the combustion efficiency in boiler.
- Conclude the energy conservation opportunities and the other way of energy utilization

2.6.4 Other Measures in Energy Conservation

Install the measurement system

- Install the necessary meter
- Check and calibrate the existing meter in the building

Maintenance the equipment correctly

2.6.5 The assessment of the obstacle and the correct of the Information data

2.6.6 The assessment of the energy conservation in the past

- The result from the measures and the investment as the Preliminary Energy Audit
- The result from the measures and the investment as the Detailed Energy Audit

2.6.7 The assessment of the person concerns the production and consumption of the energy in the building and the human resource development.

2.6.8 The result of the energy conservation management about activity management organization and also survey the opinion from the manager and the concerning person.

2.6.9 Conclusion and Suggestion

- Conclude the energy conservation opportunities.
- Suggest the appropriate measures in the view of operation and economic.
- Suggest the problem solving.
- Conclude the opinion of the operator about the Energy Conservation Promotion Act B.E.2535

2.6.10 The Attachment Document

- Thermal Analysis
- Electrical Analysis
- Detail of the Thermal and Electrical Instrument

2.7 Measures of Central Tendency

The measurement of the tendency to the central of the data is the procedure of the conclusion all data into one. The one is the representative of all data or uses for comparison the data between each group. [19,p52]

Mean or called Arithmetic mean in a symbol $\bar{X}$ is one kind of data representation.

$\bar{X}$ = $(X1 + X2 + X3 + \ldots + Xn)/n$ [20,p151]

Xn = data number n

n = number of data

2.8 Literature Survey about the Energy Audit Report

Now the report checking in Thailand is managed as the same concept as in foreign country. The reviewer checks the report as the checklist or manual. The main idea of the manual is composed of the following items. [21]

- Source of Data
- Methodology for Data
- Factor for Computation
- View of Checking (Economics, Feasibility, Reliability etc.)
- Miscellaneous

Energy Auditors Incorporate in South Carolina define his service about the energy audit report that

The energy audit report should provide the facility operator with a menu of a energy saving options that detail about estimated annual savings, estimated implementation cost, simple payback, rate of return. In addition, the energy audit report

must include the energy calculations made to estimate annual savings and implementation cost. [22]

The New York State Energy Research and Development Authority requests statements of qualifications and experience from energy service companies interested in providing comprehensive energy services on a performance contracting basis in State-owned facilities through the State Energy Investment Program. The Requirements for the comprehensive energy audit must include provisions for the performance and presentation of results of a comprehensive energy audit for each of the buildings comprising the facility. The audit must at a minimum include the following:

(a) Baseline energy use, showing how it is derived and how it may be adjusted for appropriate variables.

(b) An allocation of total energy use among end uses. The allocation must be reconciled with actual usage, and must be based on generally accepted engineering practices.

(c) A description, without specifications and drawings, of recommended energy conservation measures covering improvements to the physical plant and operating procedures. For each measures, the proposer must provide estimates of initial costs for design and installation, efficiency levels or performance characteristics of the equipment comprising the proposed

measure, ongoing maintenance costs, annual energy and cost savings, the useful life of the measure, and a life cycle analysis. Projected energy saving must account for interaction between selected measures. [23]

2.9 Pareto Analysis

The Pareto Principle owes its origins to and Italian economist who studied the distribution of wealth within Italy in 19th Century and discovered, probably with no great surprise, that 80% of the financial wealth of the country lay in the hands of approximately 20% of the population. He went on to investigate other possessions such as land, livestock etc. and found that the same pattern kept repeating it self: Around 80% of any given item related to about 20% of the population.

The Pareto Principle manifests itself in industry in several forms, but the most important of these in practical terms is in the area of problems and causes. The exact figures will vary; it may be 70 % due to 30%, however, the general principle of "The important few and the trivial many" holds goods. Thus, as a tool, it allows us to decide upon the most important areas for improvement on and analytical basis rather than relying on gut feel or less rigorous methods.

Creating a Pareto Diagram

Step 1. Ensure that data records are classified to enable the construction of a Pareto diagram.

Step 2. Decide the time period relating to the graph. This should be a convenient period where possible (e.g. an hour, a shift, a week) The period should always be kept constant to allow for comparisons when dealing with the problem concerned.

Step 3. Total the frequency of occurrence of each category for the period.

Step 4. Establish the appropriate units (e.g. number of defectives, cost, etc.) for the vertical axis, draw the axes and demark the vertical axis as necessary. Take care to ensure that the graph is easy to read. Label the vertical axis.

Step 5: Draw in the bars, beginning with the most frequency defective items on the far left. The height of the bar will correspond to the value on the vertical axis. Bars must be the same width. A category such as others may be used to denote several categories with limited frequencies and should be placed on the right hand side.

Step 6. Label each of the bars under the horizontal axis.

Step 7. Plot a line showing the cumulative total reached with the addition of each category. It is conventional for this line to be plotted in line with the top right hand corner of each bar.

Step 8. Title the graph and write briefly the source of the data. [24]

2.10 Cause and Effect Diagrams

Kaoru Ishikawa first developed cause and Effect diagram or Ishikawa diagram in 1943 at the University of Tokyo. They are closely related to brainstorming and, in effect, can be seen as a more structured form of brainstorming. It is the most widely used and probably one of the most useful in the "Seven Basic Tools" (Seven Basic Tools mean tools or techniques for quality improvement).

The principles of running a good brainstorming session extend to the running of a good Cause and Effect diagram creation process. They should be facilitated in the same way and similar rules applied. The general form of the diagram identifies the effect on the right-hand side and the causes on the left-hand side.

2.11 Pugh Matrix

Stuart Pugh studied the competitive product design situations over the number of years. The following concept selection procedure is one that has been tested and proved effective in many design situations.

Procedure for Minimizing

Phase One

1 Having established a number of embryonic solutions to the problem in hand, these solutions are produced in sketch form the same level of detail in each case

2 A concept comparison and evaluation matrix is established which compares the generated concepts, one with the other, against the criteria for evaluation as shown in table 2-1.

Table 2-1 Pugh Matrix

Concept / Criteria	1	2	3	4
A	+	-	D	-
B	+	S	A	+
C	-	+	T	-
D	S	+	U	-
E	-	-	M	-

3 It is essential that the matrix have all the visuals of all the concepts incorporated into it in order that the participants witness the patterns of emergence.

4 Ensure that the comparison of the different concepts is valid i.e. that all are to the same basis and at the same generic level.

5 Criteria against which the concepts will be evaluated are chosen. Usually these are based upon the detailed requirements of the product specification, i.e.

established are unambiguous and understood by all participants in the evaluation.

6 A datum is chosen with which all the other concepts will be compared. If a design or designs already exist for the product area under consideration, these must be included in the matrix and always form a useful first datum choice.

7 In considering each concept/criteria against the chosen datum, the following legend should be used:

+ Meaning better than relative to the datum

- Meaning worse than the datum

S Meaning the same as datum

8 Having selected a datum, and initial comparison of other concepts is made relative to the datum.

9 Assess the individual concept scores. If certain concepts exhibit exceptional strength, re-run the matrix with the strengths removed. If, as a result of running the matrix several times, the initial high scores persist, they are likely to be the best concepts with which to proceed.

10 If a strong pattern of concepts does not emerge, all appear to have uniformity of strength, change the datum and re-assess the pattern.

11 If, for example, one particular concept persists, change the datum and repeat. If the result remains the same, let the emergent strong concept assume the role of datum, re-run the matrix and assess the result.

It is preferable that the course of action detailed in 1 to 11 be carried out on a large blackboard or similar display unit as it is considered essential that all participants to the evaluation take part in the usually hectic discussions on each point and that each sees the complete picture for the whole of the period. Just described, the choice of concept remains with the participants, the matrix does not take the decisions, it is simply procedure for controlled convergence onto the best possible concept and is not composed of absolutes in the mathematical sense, the decisions remain with the user. [18]