Energy Audit–from a POET Perspective

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Abstract This paper presents a general structured framework for energy audit based on a new classification of energy efficiency in its performance, operation, equipment and technology (POET). General methodologies and tools in an energy audit are streamlined into this POET framework. An existing apartment building energy auditing process is analyzed by this POET based energy audit to find missing energy efficiency improvement opportunities, and the energy audit of a conveyor belt system in a power plant is used to illustrate an application of the approach in designing a new and specific energy audit system.

Keywords: energy audit, energy efficiency, conveyor belt, apartment building

1. Introduction

An energy audit is the process of examining an energy system to ensure that energy is being used efficiently [3]. It is the first step in energy management and the term was first used in the 1970's during the energy crisis. Different energy audit guidelines have been developed for buildings, industrial facilities and thermal power plants amongst others [12, 1, 4, 7, 3]. The terminologies and processes in these different guidelines are often dissimilar and sometimes overlap. Tools and methodologies have been developed, some simple, some complex, some common to all energy audit processes, and some more specific to a particular case study. It is frequently found that auditing processes miss important energy efficiency improvement opportunities. Therefore it is helpful to give a unified view on existing energy auditing processes.

We have recently summarized different energy efficiency components into performance, operation, equipment and technology (POET) efficiencies, and presented an application of this classification in control systems [14]. The POET framework provides a general conceptual classification to include different views for energy efficiency improvement. Therefore it is interesting to summarize and classify existing energy auditing processes under the same POET framework. To this end, this paper will give a brief introduction on the POET framework and then provide a POET based energy auditing process. Existing energy audit methodologies and tools that are commonly found in most energy auditing processes are briefly classified in a POET matrix. The conveyor belt example from [6] is recalled to illustrate these generic methodologies and tools. It also illustrates that this POET based auditing process is applicable to new scenarios not considered in literature. The second auditing case studies on an existing apartment building auditing process shows that this new POET based energy audit can discover important energy efficiency improvement opportunities neglected by a particular auditing process, and thus can be used as a tool to complement existing auditing processes. Therefore this new auditing process can be widely applied in various energy audit projects.

The layout of the paper is as follows. The next section briefly recalls the POET classification from

[14]; Section 3 presents different terminologies and basic structures for this POET based energy auditing process; Section 4 gives two case studies; with concluding arguments in the last section.

2. Background on the POET classifications of energy efficiency

POET efficiency components are explained in details in [14] and are briefly recalled here. Performance efficiency of an energy system is determined by external but deterministic system indicators such as production, cost, energy sources, environmental impact and technical indicators, amongst others. Operation efficiency is evaluated by the proper physical, time, and human coordination of different system components. Equipment efficiency is a measure of the energy output of isolated individual energy equipment with respect to given technology design specifications. Technology efficiency is decided by the efficiency of energy conversion, processing, transmission, and usage; and it is often evaluated by feasibility; life-cycle cost and return on investment; and coefficients in the conversing/processing/transmitting rate. The relations of the four POET efficiencies can be best illustrated by Fig. 1.

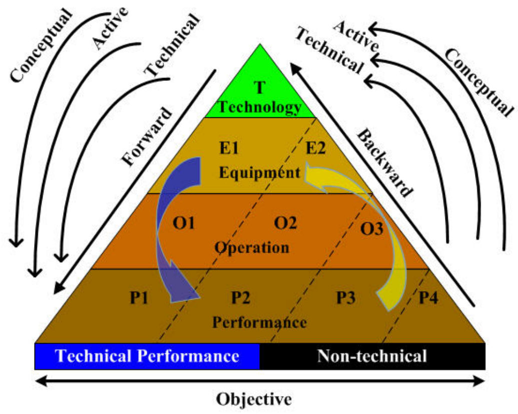

Figure 1: Energy efficiency components

Fig. 1 divides the POET components into T, E1, E2, O1, O2, O3, P1, P2, P3, and P4. T represents that technology is a deciding factor to equipment, operation, and performance efficiencies. E1 denotes the kind of equipment efficiency directly affected by technology efficiency, while E2 is the part not directly affected by technology efficiency such as equipment maintenance.The other components are defined similarly, for instance, P3 is the operation efficiency part determined by O3, and it could be the 'soft kWh' resulting from the operator's skills in O3 in many cases.

Energy management activities consist of forward and backward ways of putting these energy efficiency components together so that sustainability is achieved. The forward method moves from technology efficiency to performance efficiency, and usually an *energy audit* [12] process will be done. This initial energy audit process is to profile energy consumption and to identify the energy saving opportunities. Afterwards, one can move backward from performance to technology efficiency to perform *energy system planning* [8] consisting of policy support and the organization structure. The planning will eventually impact the implementation of technology efficiency. This cycle is called a *conceptual cycle* for the purposes of this discussion. Thereafter, one may start again from the improved technology efficiency and move to performance efficiency. This process involves an *active audit* to be done. Upon completion of the active audit stage, an *active objective* with targets and possible margins will be obtained. From this active objective/target, one may again go back to performance efficiency, and finally reach technology efficiency. This backward process is now in an *active planning* stage by listing, putting together, prioritizing and eventually implementing technical options and alternatives. At the completion of the active planning stage realistic energy efficiency improvement will be reached. This cycle is called an *active cycle*, and the energy management can now be continued, going into a new cycle termed the *technical cycle*. Technical issues such as metering, creating a baseline, monitoring, evaluating, calculating energy usage, verifying saving targets are considered. Making dedicated engineering comparisons, combinations, and optimization of technical solutions are also considered in the technical cycle. These strategic cycles provide indications of the financial viability for the energy efficiency improvement.

The strategic cycles in energy management must be supported by *engineering cycles* which can be represented by the cycles inside the triangle in Fig. 1. In an engineering cycle, one starts from technology efficiency and moves to performance efficiency to begin the *energy modeling* [9] process, then a baseline is obtained. From this baseline, one moves backward from performance efficiency to technology efficiency through the *energy optimization* [9] process. This engineering cycle can also be repeated. The engineering cycle in its content may overlap with the technical cycle at the strategic level, but it is often used to provide a technical viability analysis for the energy system.

3. POET based energy audit

There are various activities in an energy audit: interviewing of facility employees and workers; building envelope analysis; technical document analysis; measurements; energy balance analysis; energy consumption and specific characteristics; estimation of saving potentials; development of energy conservation measures; life cycle cost analysis; etc. These activities are classified quite differently in different energy audit guidelines. The guideline in [1] defines energy audit consisting of scheduling, walk-through brief and in-sight thorough stages; the Hong Kong guideline [3] classifies energy audit into walk-through audit and detailed audit only; [12] gives the walk-through level, standard audit level, and computer simulation level for energy audit; [10] summarizes the apartment building auditing processes into field work, data analysis, and reporting; [18] presents the qualitative, quantitative, and continuous commissioning levels for audit. Various terminologies exist among these guidelines: walk-through audit, follow-up audit [10], post-acceptance audit [10], on-site analysis [18], electrical audit [1], thermal audit [1], etcetera. There are also many methodologies and tools used in energy audits: energy calculations, energy flow analysis, energy modeling, control and optimization, and various diagrams and charts amongst others. The principles in these guidelines to classify the various auditing activities are based on different understandings of the energy auditing procedures and contents. Therefore it is interesting to present a new understanding on energy audit by the POET energy efficiency classifications and find out its corresponding practical applications. Since [12] is the most popular auditing handbook and the auditing procedures in [12] and [18] have more similarities than other guidelines to the POET based audit, the definitions of energy audit stages in [12] and [18] are compared to the POET based definitions in the following.

Energy audit is defined in this paper as the process of analyzing an energy system and identifying, validating and evaluating energy efficiency improvement opportunities. According to the previous section, energy audit consists of three stages: conceptual energy audit stage, active energy audit stage, and technical energy audit stage.

Conceptual energy audit is a process to tell where changes will take place to improve energy efficiency, and energy consumption profile is established in this process. The keyword for this conceptual stage is *identification* which implies that this stage aims at identifying energy efficiency improvement opportunities. Usually it uses the least effort to identify the greatest energy saving opportunities, say, 20% effort with 80% savings. It often includes efforts such as walk-through visit of the energy system to identify possible energy leakage, waste, or other losses; the analysis of energy consumption data to find consumption profile, compare with benchmarks, and analyze energy balance. This stage is similar to the 'Walk-through' level in [12], and it is covered by the Level I audit (qualitative analysis) in [18] which has overlaps with the following active energy audit too.

Active energy audit is a process to decompose and prioritize system components/sectors to further explore and consolidate energy efficiency improvement opportunities. The keyword for this stage is *validation* which implies that energy saving opportunities will be validated in this stage. It often needs extra metering and data, thus it may include activities such as detailed analysis on different components of the energy system; installations of new meters when necessary to aid the energy consumption analysis of system components and processes. This stage is similar to the 'Standard Audit' in [12], but different from Level II (quantitative analysis) in [18] as the latter overlaps with the technical energy audit defined below.

Technical energy audit is an *evaluation* process which involves more technical activities to evaluate energy saving opportunities. For example, energy system modeling and analysis, energy analysis software tools, energy optimization and control tools, amongst others, are often needed to further improve energy efficiency. This includes the 'Computer Simulation' level in [12] and may involve more advanced human intervention on energy modeling, optimization, and control analysis which are often beyond the scope of existing computer simulation software. The Level III audit (continuous commissioning) in [18] is different from this technical energy audit since it involves also implementation and fully instrumented diagnostic measurements, which belongs to the energy planning and measurement and verification process in this paper [14].

For each of these three stages, there is a corresponding POET structure. For instance, the conceptual/active/technical performance energy audit can be defined below.

Conceptual/Active/Technical performance energy audit: This is a kind of conceptual/active/ technical energy audit which focuses on the performance efficiency of the underlying energy system, that is, the performance efficiency indicators of the energy system, such as production, cost, sources and environmental impact, will be studied to identify/validate/evaluate energy efficiency improvement opportunities.

Similarly one can define Conceptual/Active/Technical operation, equipment and technology energy audit. It is worth noting that the above performance, operation, equipment and technology auditing processes may not have clear-cut boundaries since the POET components have no strictly defined boundaries and may also exist at micro-level underneath a more visible macro-level, exhibiting a multi-layer structure [14]. In practice, it is not uncommon that two stages of energy audit are carried out concurrently.

4. Methodologies and tools of energy audit from a POET perspective

Existing methodologies and tools for energy audit can also be classified from the POET perspective as Fig. 2 illustrates.

Here are some examples which are classified in terms of the POET matrix Fig. 2. These examples are common methodologies and tools used in various energy audit practices, and specific methodologies and tools may need to be further investigated and developed for specific projects, although both the common and specific methodologies and tools can be put into the POET matrix in Fig. 2. For conceptual audit, walk-through site visit, collection of utility meter reading, and load profile analysis [12], [1] amongst others are possible audit methods. Questionnaires, pie charts for load profiles,

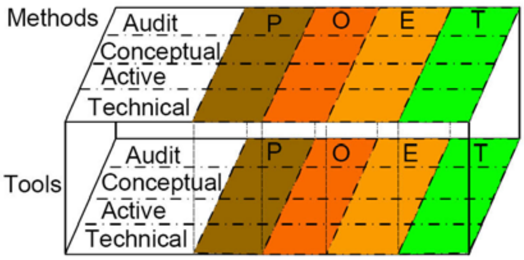

Figure 2: Methodologies and tools in energy audit

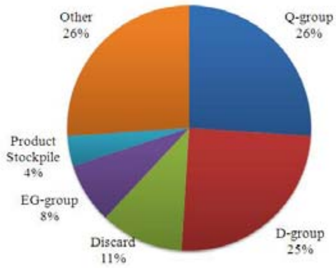

Figure 3: Percentage contributions of different parts in a conveyor belt system

scattered plots, building plans, and energy flow charts can be used as audit tools for both conceptual and active audits. In an active audit, typical examples of audit methods include installation of metering and monitoring instruments, log and check-up, disaggregated load profile analysis, etc, and the audit tools cover attribute-cause charts [5] and checklist and control charts [13, 5], amongst others. The technical audit methods could be energy system modeling [9], model validation, even new technology investigation, while the technical audit tools could be chosen from, but not restricted to, the various simulation and optimization toolboxes and regression analysis software.

Each of the methods and tools could be further classified by investigating if it is focused on any of the POET components and a particular method or tool can cover more than one POET components. For instance, collection of utility meter readings is a conceptual audit method for analyzing the cost related energy consumption of the whole energy system, therefore it can be classified as focusing on operation efficiency. If the questionnaire is taken as a conceptual audit tool, and if the questionnaire is focused on the energy cost, energy resources or environment impact, then it is classified as focusing on the performance efficiency; however if it covers also the system operating time and maintenance, then it can should be classified as focusing on the operation and equipment efficiencies as well.

The audit tools may be suitable for one or more POET components, for instance, questionnaires and various energy audit software can be designed for all four POET components; control charts, attribute-cause charts, energy/power consumption pie charts, energy balance diagrams and disaggregated load profiles are better suited for operation efficiency; energy-time charts can be applied for performance and operation efficiencies; tables, checklists and spreadsheet are powerful for performance and equipment efficiencies; Microsoft Office Excel, Matlab, and various control and optimization toolboxes are recommended for technology efficiency; etc.

There are many existing software tools which integrate many component blocks in Fig. 2. For example, BDA 3.1 (Building Design Advisor) developed by the Lawrence Berkeley National Laboratory provides a data managing and process control toolbox for building design and auditing[1], and this software integrates conceptual, active and technical auditing processes together.

Fig. 4 illustrates the process flow of a conveyor belt system in a coal mine studied in [6]. The conveyor belt system consists of several groups of conveyor belts, for example, the Q-group, P-group, D-group,

[1]http://gaia.lbl.gov/BDA

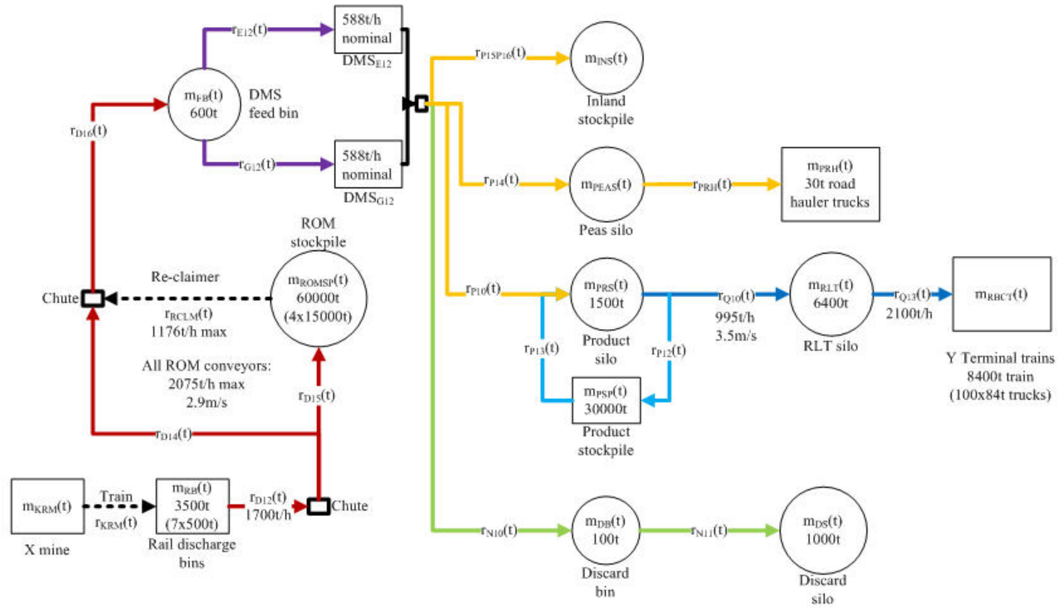

Figure 4: Process flow of a conveyor belt system

E-group, N-group, or more. A one-month real-time electricity consumption data for different parts of the conveyor belt system are collected in the active performance energy audit stage. Then the active audit tool, pie chart, is utilized in Fig. 3 ([6]) to visualize the averaged energy consumptions of different components of the conveyor belt system. Since the electricity cost as a performance efficiency indicator is selected to evaluate the operation efficiency, this pie chart serves as an active performance audit tool in this case. Q-group conveyor belts are selected in [6] as the target group of load shifting in terms of a time-of-use (TOU) electricity tariff since Q-group consumes the greatest proportion (26%) of the total electricity consumption, and the three silos in Q-group have a great storage capacity for load shifting purposes. This prioritizing of system components also happens at the active performance audit stage.

5. Case studies

5.1. Energy audit of building envelopes

[10] provides a comprehensive auditing process and also a sample auditing report for the energy audit of apartment buildings. This process includes the site survey and visit, data analysis with modeling and energy saving points identification, reporting and energy efficiency certificating. This audit covers the following energy and water consumption objects: floor heating system, electrical system, domestic water system, ventilation system, space heating, and insulation of the building envelope. By the POET based energy audit definitions, this energy auditing process in [10] can be re-organized and re-understood as follows.

a). Conceptual/Active/Technical performance audit

In this stage, performance efficiency indicators such as cost, production, sources, and environmental impact, are analyzed to identify/validate/evaluate energy efficiency improvement opportunities. For example, in the conceptual performance energy audit, the cost indicator is considered by analyzing the energy cost of the building and this is typically done in most of the building auditing processes; the production indicator can be understood as the indoor temperature resulted from the Heating, Ventilating and Air Conditioning (HVAC) system; the energy source indicator includes the energy supply to the building: electricity, gas, steam, solar or wind and more. [10] considers the environmental impact and renewable energy in its general means of promoting and monitoring energy conservation measures. However these can be included in the apartment building energy auditing process. In fact, the trade-off between the comfort level of the occupants (e.g., the indoor temperature) and the pollution resulted from the HVAC system; the proportion of green energy (e.g., solar and wind) to the total energy consumed; can also be included in the energy audit.

b). Conceptual/Active/Technical operation audit
For these different stages of operation energy audit, the operation efficiency indicators such as the physical, time and human coordinations should be considered. This includes the sizing of lighting systems and HVAC system, and possibly the interactions of the two systems, to meet necessary illumination and indoor environment requirements; load shifting or reduction of water heating or HVAC systems in terms of TOU tariff to save energy cost; skill levels of relevant staff, etc; which are valuable additions to the procedures in [10]. As an example of operation audit, the following strategies among other things can be adopted to complement the auditing process in [10].

• Simple load reduction and skill training for conceptual audit: For example, a Power Conservation Programme [2] may require major industrial users to reduce 10% of their energy consumption and 10% of maximum demand during peak hours. In this case, the simple switching off of certain unimportant HVAC system in an apartment building at peak hours will be helpful to reduce the the maximum demand and total energy consumption.

• Simple sizing and load shifting of facilities for active audit: For example, the number and power rating of light bulbs in each room should match the skylight level, occupancy and illumination requirement amongst others. The power of an air conditioner in a room should also match important indices of the room such as the area, height, orientation, occupancy and special temperature requirements. Facilities with certain storage capacity can be operated for load shifting to save maximum demand and energy cost. For example, the loads of hot water geysers can be manually switched off during peak time and switched back on during off-peak periods.

• Optimal load shifting: For instance, an automatic timer can be installed to automatically control the switching on/off of a hot water geyser according to the user's hot water consumption profile and a TOU tariff. This process may need a complex energy modeling process related to water stratification and optimal control [15] [11].

c). Conceptual/Active/Technical equipment audit
These equipment energy audits need to consider the equipment efficiency indicators such as capacity, specifications, constraints, standards and maintenances amongst others. The improvements of thermal installation of the structure (windows, external walls, etc) in [10] are examples of the equipment energy audits. The maintenance of existing equipment (building envelope, electrical and thermal systems, and others) will also improve energy efficiency and this is supposed to be solicited in [10].

d). Conceptual/Active/Technical technology audit
These three levels of technology energy audits improve energy efficiency in terms of technology

Tripper car No.		Description	
Model		Manufacturer	
Staith No.		Time	
Performance audit	Voltage, Current, Power factor, and Power of the tripper car; Average feeding rate of this tripper car (t/h);		
Operation audit	Average feeding operating hours per day (h):		
	Power consumption when the tripper car is moving (kW):		
	Average operating hours per day when the tripper car is moving (h):		
	Power consumption when the tripper car is feeding (kW):		
	Average operating hours per day when the tripper car is feeding (h):		
	How the moving routes are determined for this tripper car:		
Equipment audit	Supply votage (V), rated power (kW), rated power factor, and efficiency (%) of the driving motor; Rated capacity of the tripper car (t/h);		
Other parameters or comments:			

Table 1: Specifications of each understaith tripper car [16]

efficiency indicators including feasibility, life-cycle cost and coefficients in the energy conversing/ processing/transmitting rate. The modeling of the total energy costs before and after possible energy efficiency improvements, and the payback time calculation for various investments in [10] are typical examples in these technology audits. The optimal load control method is often applied in technical technology audit and this has yet to be emphasized in [10].

From this example one can draw the conclusion that the POET based energy audit will be helpful to complement existing auditing processes.

5.2. Energy audit of conveyor belt systems

The energy efficiency improvement of conveyor belt systems plays an important role in the total operational cost of systems handling bulk materials. The POET based energy audit for conveyor belt systems in coal-fired power plants has been done in [16] and it is applicable to general conveyor belt systems. This energy auditing process is briefly introduced as follows.

The conceptual energy auditing process is a questionnaire with simple questions focusing on different POET components. For instance, the conceptual performance audit part will collect information on whether the capacities of the conveying systems are over designed, whether a TOU tariff has been considered in the operation, whether the supervisory control and data acquisition system is available, whether the feeding rates of the conveying systems match the capacities of the conveyor belts and whether there is non-technical energy losses (theft or earth). These questions are yes or no type of questions only, and the confidence level of each answer has been collected too so that the reliability of the answers can be obtained.

The active energy auditing process is also designed as a questionnaire with various tables and choice questions to fill, and such a questionnaire is supposed to be handed out to relevant technical staff. For example, at the active equipment auditing process, tables are designed to collect information on the capacities, qualities, models and manufacturers of conveyor belts, understaith tripper car, electro-magnets, bunker tripper car, belt cleaner, dust extraction fans, dust suppression system pumps, sump pumps, etc. Equipment specifications, such as quantity, rated power, average power, average operating time and total energy consumption per day are also collected for the above mentioned equipment. Specific questions are asked for important equipment such as conveyor belts and the understaith tripper car. For instance, the questions for the conveyor belt include meter readings of belt speed, feed rate, power factor, voltage, current and power; average loading rate; daily average operating time; horizontal centre-to-centre distance; supply voltages and rated powers of drive motors; hydraulic coupling efficiency; amongst others. Table 1 is taken from [16] to illustrate how the active energy audit is done for the understaith tripper car. Some important questions concerning performance, operation and equipment efficiency indicators are asked. Technology efficiency related questions are not asked since the main focus of this active audit is to find quick win solutions and technology efficiency improvement is mainly left to the technical audit stage.

The technical energy auditing process includes the energy modeling of the conveyor belt system [17], the optimal load shifting of conveyor belt systems [6], the adoption of variable speed drives, and the integration with renewable energy systems amongst others. Among these measures, the energy modeling of the conveyor belt is part of the technical technology audit, the optimal load shifting belongs to the category of technical operation audit, the adoption of variable speed drive is covered by technical equipment audit, and the integration with renewable energy systems can be understood as technical performance audit. The technical audit on the optimal load shifting for the specific conveyor belt system in [6] can be illustrated as follows. After the prioritizing of the Q-group as the load shifting objective (see the end of Section 4), a technical technology audit method, energy system modeling, is chosen to obtain the following optimal control model:

$$\begin{array}{ll} \min & J = \int_{t_0}^{t_f} \sum_{i=1}^{n} P_i u_i(t) p(t) \mathrm{d}t, \\ \text{subject to} & g(u(t), t) \leq 0. \end{array}$$

where $[t_0, t_f]$ is the load shifting time period, n is the number of conveyor belts; P_i and $u_i(t)$ are, respectively, the power and switching status of the i-th conveyor belt; $p(t)$ is the TOU price function at time t; and $g(u(t), t) \leq 0$ denotes various system operational constraints. After that, the *bintprog* function from the Matlab Optimization Toolbox, is selected to solve this optimization problem. This process is highly technical, it is mainly an engineering research and development exercise. However, it is also important to incorporate a financial viability into the technical viability study. The minimization objective function represents the cost of electricity. [6] showed in the case study that the operation efficiency improvement driven by the cost of electricity as a performance efficiency indicator can indeed reduce about 25% of the energy and 50% of the energy cost in one working week. The first criterion of sustainability of an energy management programme is the compatibility of a financial indicator and a technical indicator, i.e., it should make both financial and energy sense. Establishing the financial viability of this technical exercise, is in itself an essential step towards a technical audit. From this example, it can also be seen that the three basic components: energy auditing, energy targeting and energy planning, form an integral, sometimes an inseparable especially in the technical and engineering cycles, whole unit in energy management.

6. Conclusion

This paper presents an energy audit designing processes based on a new energy efficiency classification– the POET classification. This POET based energy audit can be used to complement existing auditing processes by identifying missing important energy efficiency improvement opportunities. It can also be applied to specific energy auditing processes as the case studies illustrate.

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References

[1] Centre for Renewable Energy Sources, Energy Audit Guide (Part A, B, C), European Commission, Athens, May 2000.

[2] Department of Minerals and Energy of South Africa, National Response to South Africa's Electricity Shortage, Jan. 2008, Available: http://www.dme.gov.za/pdfs/energy/national_resp_plan.pdf

[3] Electrical and Mechanical Services Department, Guidelines on Energy Audit, The Government of the Hong Kong Special Administration Region, Hong Kong, 2007.

[4] Indo-German Energy Programme, Guidelines for Energy Auditing of Thermal Power Plants, EVONIK Industries, January 2009.

[5] Industrial Technology Research Institute, How to Set Up Energy Audit System, Taiwan, http://emis.erl.itri.org.tw/english/brochure/list.asp

[6] Middelberg A, Zhang J, Xia X, An optimal control model for load shifting– With application in the energy management of a colliery, Applied Energy, vol. 86, 2009, 1266-1273.

[7] Milan CB, A Guidebook for Performing Walk-Through Energy Audits of Industrial Facilities, Bonneville Power Administration, 2001, http://www.bpa.gov/indexmain.shtml

[8] Owens S, Energy, Planning and Urban Form, Pion Limited, London, 1986.

[9] Rajan GG, Practical Energy Efficiency Optimization, PennWell Books, Tulsa, 2006.

[10] Silvonen S, Markovitch J, Naumov G, Guidelines and Models for Energy Auditing, PHARE and INTERREG funded project report, Motiva Oy, Finland, 2006.

[11] Thomas R, Xia X, Zhang J, Energy efficient geyser, The 16th International Conference on Domestic Use of Energy, Cape Town, 18-19 March 2008.

[12] Thumann A and Younger WJ, Handbook of Energy Audits, 7th Edition, The Fairmont Press, Lilburn, GA, 2008.

[13] Wheeler DJ, Chambers DS, Understanding Statistical Process Control, Second edition, SPC Press, Knoxville, Tennessee, 1992.

[14] Xia X, Zhang J, Energy efficiency and control systems–from a POET perspective, in: IFAC Conference on Control Methodologies and Technology for Energy Efficiency, Vilamoura, Portugal, 29-31 March 2010.

[15] Zhang J, Xia X, Best switching time of hot water cylinder-switched optimal control approach, IEEE AFRICON, Namibia, 26-28 September 2007.

[16] Zhang S, Xia X, Energy Auditing for Coal Conveying Systems in Coal-fired Power Plants, Centre of New Energy Systems, University of Pretoria, 2009.

[17] Zhang S, Xia X, A new energy calcualtion model of belt conveyor, IEEE AFRICON 2009, Nairobi, Kenya, 23-25 Sept. 2009.

[18] Zhivov AM, et al, Energy and Process Assessment Protocal for Industrial Buildings, IEA ECBCS Programme Annex 46, Subtask A, v.2.0, September 2006.