TOTAL PRODUCTIVE ENERGY MANAGEMENT

Mohammad S. Al-Homoud, Ph.D.
Ass. Prof. of Architectural Engineering Department
Dirctor, Office of Energy Management
King Fahd University of Petroleum & Minerals
Dhahran 31262, Saudi Arabia

ABSTRACT
The energy issue is becoming a determining factor in the living standards of individuals as well as societies. The increasing demand for increased productivity, improved quality of products/services, reduced environmental emissions, and reduced energy costs are all incentives for organizations to invest in and implement new energy efficiency technologies and management approaches. This necessitates a collective effort towards the efficient and wise utilization of all energy resources. This paper introduces the concept of Total Productive Energy Management (TPEM). This approach would require the involvement of all members of a facility to take part in energy conservation activities in their facility by being responsible for the management of energy systems in the space(s) they occupy and/or the equipment they operate. Top management commitment, incentives to employees and continuous training are the means of implementing such an approach in organizations. This approach will help implant the awareness and commitment to energy conservation on all levels, therefore saving money and protecting the environment.

INTRODUCTION
Contemporary facilities house a lot of complex systems, most of which require power to operate. Computer-intensive applications are becoming the norm in large as well as small organizations. In addition to the energy needed for the day-to-day operation of these energy systems, the burden they impose on HVAC systems as a result of heat generated by the equipment can have a significant impact on the consumption of energy in the facility. This places the operators and users of these facilities in competitive roles with regard to their respective share of available energy. This fact can no longer be ignored.

Facility energy systems are interrelated as shown in Figure 1. The amount of energy required to air-condition or light a space, for example, depends on how well the envelope of that space is thermally designed as well as its capability in utilizing natural light and ventilation. The various energy systems in a facility interact to achieve the desired environment and/or process. Any shortcoming or deficiency in the performance of one of these systems would have to be compensated for by other systems, otherwise the desired objectives would be compromised. The impact of the performance of such systems would be reflected on the quality of the environment, productivity and long-term economics of the facility. Early design considerations therefore, are critical in determining the comfort and energy needs of a facility. A total systems approach of energy management that considers all systems together and their interaction as one system is also critical in achieving the desired objectives of energy management programs.

Proper operation and maintenance of such systems will also have a great impact on their consumption of energy. Therefore, it is important to give enough attention to the training and awareness of the energy issue, particularly to building operation and maintenance personnel as well as those involved in the production and/or use of the workplace in the facility. Even

for energy conscious designed facilities with the most energy efficient systems and equipment, full utilization of energy conservation benefits cannot be achieved without proper operation and maintenance. It is these day-to-day operations that have the greatest impact on energy consumption. Although they cannot be easily quantified, energy savings resulting from operation and maintenance personnel training, facility users awareness of the energy issue, as well as their active involvement in its management, can be significant.

Total Quality Management (TQM) is an approach to doing business with the objective of maximizing the competitiveness of an organization through continuous improvement of the quality of its people, products, services, processes and environments. The TQM approach focuses on increased customer/user satisfaction through continuous integrated improvement activities that involve everyone in the organization from top management to the workers. [1]

The concept of Total Productive Maintenance (TPM), defined as *productive maintenance with all employees participating through small-group activities* was first introduced in Japan in 1969. It implies the involvement of all members of an organization in the periodic maintenance of the equipment they operate. It became widely utilized in Japanese automated industry. Its implementation created a productive environment and commitment in maintaining the facility from the worker to top management, which resulted in reduced equipment failures, improved equipment effectiveness, reduced rate of defects, reduced claims, reduced maintenance costs, and increased productivity. [2]

This paper introduces the concept of Total Productive Energy Management (TPEM) which follows the similar approaches of TQM and TPM and involves all individuals in a facility in managing energy systems under their control, the aim being retained quality environment/product at reduced operating costs.

WHAT IS ENERGY CONSERVATION AND MANAGEMENT?

Energy conservation means assessing the need for a certain task or using less energy to achieve the same task. The main objective is to effectively manage available energy sources to operate a facility in the most efficient way. There are two aspects of energy conservation:

1. Energy Efficiency

This aspect implies using less energy with no sacrifice on the part of the individual or the society. An example would be heating a room to the desired temperature with less energy through improving house insulation, the design of a more efficient heater, a combination of both or some other change that would improve the efficiency of the heating system within the building. This aspect primarily involves issues of economics and technology and requires the proper approach(s) for implementing the available technical aspects within given economic constraints.

2. Energy conservation involving user sacrifice

This aspect, on the other hand, implies using less energy if we are willing to make some sacrifices with respect to comfort and/or quality of of living standards. An example would be cooling/heating the house with higher/lower room temperature (higher/lower thermostat setting) or hanging laundry in the sun rather than using a dryer. This aspect involves sacrifice, compromise and change in the standards of living.

Measures of energy conservation within acceptable limits of comfort and function could help in solving the energy problem. However, total building performance as an optimal operation of one component/system might not guarantee optimum overall performance, as component/system interaction could increase other costs and/or sacrifice quality function objectives of the organization or facility. Therefore, *"Energy efficiency and/or energy conservation efforts should not be equated with discomfort, nor should they interfere with the primary function of the organization or facility. Energy conservation activities that disrupt or impede the normal functions of workers and/or processes and adversely affect productivity constitute false economies"* [3: 342.3]

It is important to recognize that energy conservation technical measures alone are not enough. One might employ the best technology with the most efficient systems but, without proper energy management, these efforts might result in false economies.

Many definitions exist for energy management, all of which agree on the same objective of achieving the same task for less energy use without sacrificing the quality of the environment and/or products through the employment of capital, technology and management skills. Any activity that improves the use of energy falls under the overall definition of energy management which has a wider scope than just conservation [4]. Examples of this include:

- Conserving energy in a facility
- Raising awareness for energy conservation
- Developing strategies for wise energy usage
- Keeping track of energy use in a facility
- Researching and employing technology to conserve energy
- Managing energy supplies and reducing interruptions
- Utilizing new technologies and/or equipment for energy conservation

WHY ENERGY MANAGEMENT?

There are many reasons for adapting energy management programs in facilities. These reasons can be summarized as follows:

1. ***The Principle of Saving Natural Resources***

Usable resources are made available to mankind to be utilized for their benefit and well being. Every individual bears the responsibility of not wasting or misusing usable resources. All moral codes are against such actions. Therefore, every individual should be educated and trained to become part of the management of resources for the benefit of generations to come.

2. Economic Benefits

The objective of commercial organizations is to maximize profit while the objective of non-commercial organizations is to allocate savings in one area to other important tasks. An energy cost is an operating cost, and savings in this area could be continuously utilized. Many measures can be employed to save energy, some of which involve nothing more than wise use and operation of energy systems within a facility. Others might require capital investment but would bring long-term benefits. Studies on energy conservation have shown that there is much potential for great energy savings in various projects. As much as 5-15% savings can be achieved with little or no capital expenditure, 15-30% is a common energy saving and 30-50% savings can be obtained with capital investment [5].

3. Protection of the Environment:

In a world with serious environmental safety concerns, the need is growing for more technical, political, and management activities to use clean, safe and economically feasible energy as well as contributing to lessened production of environmentally damaging products such as acid rain and ozone depleting CFC products. Energy management is the first step towards achieving such objectives. Mazzo [6] presented the case studies of five energy projects, which not only saved millions of dollars as a result of reduced energy consumption, but also resulted in great environmental benefits in the respective locations as emitted pollutants were reduced.

4. Customer Satisfaction and National Good:

Energy management results in wise utilization of available energy resources that will reflect well on the individuals concerned as well as society as a whole. The outcome of the implementation of effective energy management programs will result in:

- Making energy available to others
- Decreased customer costs
- Fewer interruptions (better service)
- Savings in electricity generation costs
- A reduction of costs required to install new power generating plants to meet increased demand
- An extension of the life of finite energy resources
- Conservation of resources for future generations

Therefore, an important ingredient of energy management is the human dimension and its involvement in the overall scheme of things. Employees and end users participation in managing energy sources in a facility is crucial in determining the success of energy management activities. Their involvement into management behavior is a basic principle of the newly introduced approach of Total Productive Energy Management as explained in the following sections.

THE TOTAL PRODUCTIVE ENERGY MANAGEMENT (TPEM) APPROACH

The quality of the indoor environment is becoming a determining factor in the value of today s facilities as well as in achieving the strategic missions of organizations. Satisfaction of the facility s customers (external customers or internal employees) with the quality of service provided is a determining criteria. Internal employees receive a service and provide a service. They receive the service of a quality indoor environment suitable for them to perform their duties. They provide external customers with a physical product or a service. In the long run, the quality of an externally provided service is influenced one way or the other by the quality of internal service received.

The increasing demand for increased productivity, improved quality, reduced environmental emissions, and reduced energy costs are all incentives for organizations to invest in and implement new energy efficiency technologies as means of energy management. However, the success of such energy management activities can only be determined by the wise use of those for whom the facility/equipment is designed. Their participation in operating the equipment and managing the space(s) they use is crucial in getting the most out of all technical efforts. More involvement of employees in decision-making related to their lives should be incorporated into management behavior. In certain organizations, the extent of

conservation is directly related to the degree of employee involvement in conservation efforts [7].

The Role of Operation and Maintenance in Energy Management

Operation and maintenance (O&M) related decisions start in the design stage of the facility via planning, zoning, materials, and equipment selection. Proper maintenance helps to eliminate defects and breakdowns which enhances systems and equipment operation, resulting in lowered operational costs. Proper maintenance strategies such as the implementation of total productive maintenance (TPM) in manufacturing processes, for example, not only helped to improve productivity, but as much as 30% of energy was conserved in one of the companies that received of the TPM prize in Japan [8: p3].

Operation and maintenance personnel involvement in the design process is essential. Their feedback on O&M related issues can help designers avoid repeating the same mistakes in future projects. O&M personnel know about repetitive failures and defects and have experience that can be utilized in improving the redesign/design of existing/new facilities/products. Operators report failures, inefficiency, and misuse and may be involved in maintenance aspects related to energy conservation in their workspace. Poor maintenance and facility operation in a use-until-it fails mode or only following complaints might result in short-term reduced maintenance costs. However, long-term overall costs might increase due to the resulting reduced facility lifetime as well as increased energy operating costs.

The problem with facility O&M is that effective management aspects do not produce readily measurable results. This makes the economics of O&M activities difficult to evaluate and savings hard to quantify [9]. However, it is important not to ignore the economics of quality. Proper operation and maintenance might not produce short-term measurable benefits, but it will help improve energy systems efficiency, resulting in lessened energy operating costs and comfortable and healthy environment; improving morale and creating a better work environment. The overall result is user satisfaction and better productivity. An improved value of the facility will also be obtained in terms of rent and/or market value. All these outcomes require a long-term economic perspective.

Studies indicate that behavioral based management aspects related to the operation of facility energy systems can have a significant impact on energy consumption. The impacts of selected HVAC and lighting systems maintenance and operation problems of lighting management, fan control, thermostat setting and economizer control on energy consumption were assessed in an office building in three different US climates using building energy simulation analysis. Results indicated that savings ranging from 10% for thermostat settings to 50% for lighting management could be achieved [9]. These measures require no capital investment other than proper operation and maintenance and user awareness and participation.

Feedback from operation and maintenance via maintenance personnel and end users is very important and useful input for improvements in the design of new facilities and/or renovation of existing ones, as illustrated in Figure 2. The behavior of facility operators/users can have a significant impact on energy consumption. They should be part of the energy conservation campaign. It cannot be successful without operator/user involvement. The effectiveness of maintenance procedures will influence the performance of energy systems serving the facility. The operation of such systems is related to facility user behavior, which cannot be ignored. Building automation, if properly designed and maintained, can help reduce reliance upon human and managerial aspects.

TPEM Objectives

Facility TQM is an integrated approach to facility operation and is based on the principle that front-line employees should have the authority to make changes and other decisions at the lowest operating levels [5]. Total productive maintenance (TPM) means that operators are responsible for the maintenance of the equipment they operate. The concept of TPM integrates operation and maintenance by operators and therefore focuses on the equipment users (input side) of production as compared to Total Quality Management (TQM) which focuses on the quality of the product (output side).

Can the concepts of TQM and TPM, applied successfully to the manufacturing processes, be applied to energy management? They can if unified objectives and enough motivation and teamwork with limited barriers between departments and employees exist. In a similar combined approach to that of TPM and TQM, the concept can be extended to total productive energy management (TPEM) where the employees of an organization become responsible for managing energy systems in the space(s) they occupy and/or equipment they operate.

The objective of the proposed TPEM approach is to motivate all those involved in the operation/use and maintenance of a facility to achieve the same tasks with minimum use of available energy resources. This requires an optimum use of required energy inputs to produce the required quality outputs (physical products or services). Their involvement can be extended to improve the efficiency of energy systems in new and/or existing facilities through feedback on failures and inefficiencies to the design, engineering and production teams.

TPEM aims at improved quality of the working environment at decreased cost while increasing morale and improving safety and health conditions through the management of energy resources and increased equipment efficiency. It focuses on formulating scattered behavioral-based energy conservation activities in an organization in a structured framework integrated with effective energy systems in order to optimize the overall operation of the facility through people involvement and shared responsibilities. Therefore, the main objectives of TPEM can be achieved by:

1. changing corporate culture in order to maximize the overall effectiveness of all energy systems in the facility;
2. involving the various departments (design, engineering, production, operation and maintenance as well as administrative) through continuous feedback and exchanged experiences;
3. the participation of every employee in the organization;
4. the promotion of TPEM through motivation management and through group activities supported by awareness, training, and financial and social incentives.

Based on the same concepts of TQM and TPM and to achieve these objectives, the need for the following should be realized:

- Strategic planning based on a scientific approach
- Economics of quality (management for quality at least total cost); invest more for quality systems, equipment and human resources development for long-term benefits and total cost minimization; quality requires an economic perspective with long-term thinking
- Established targets

- Unified objectives, a sense of belonging to the facility (one family, limited barriers between individuals and departments, conservation is everyone s job)
- Top management commitment
- Long-term commitments
- Encouragement of informal teamwork and cooperation
- Involvement of employees in decision making (operation & maintenance); operators know more about their space needs and efficient equipment operation (seek their input and get them involved)
- Making managing energy resources a habit; managing behavior requires changing habits
- Enhancement of productivity by making conservation of energy part of the production process (integrate energy management with operation & maintenance)
- Reporting achievements
- Adapting performance measures; metering and submetering records might be utilized to assess consumption and savings and for evaluation of employees efforts in managing energy systems in their work environment for rewards and other incentives
- Rewarding success makers
- Continuous education and training
- Continuous improvement
- Total energy management not just conservation

It is important to recognize that behavioral approaches to energy conservation are at least a prerequisite for more capital intensive conservation measures and neglecting them might lead to the failure of the capital projects [7]. A successful TPEM program requires all involved to understand and appreciate the answers to some questions of concern as illustrated in Figure 3.

Implementing TPEM

In some organizations, energy management activities have already started in one way or the other but not necessarily in a well-structured framework. In many other organizations, on the other hand, energy management issues have not been considered seriously. Therefore, it is important to address energy management in a systematic and planned approach. In all organizations, those with active energy management programs as well as those without, management commitment and support and employees participation are prerequisites to a successful TPEM program. Most of the basic principles of TPEM are just good management techniques. The challenge comes in implementing these techniques involving people with different backgrounds, different needs, and different expectations. It will be up to the management not only to initiate TPEM but more important to maintain it active.

In a similar approach to that of implementing TPM [2,8], the following steps formulate the procedure for implementing TPEM in an organization:

Initiation stage:

1. Establish top management commitment to TPEM implementation;
2. Announce top management decision to introduce TPEM through memos, organizational public seminars and media announcements;
3. Establish TPEM promotion staff and form TPEM promotion teams through organization-wide promotion committee, departmental promotion committees, and special working groups;
4. Launch an awareness and education campgain to familiarize people with TPEM through meetings, general seminars, presentations and posters;

5. Establish TPEM policies and goals by analyzing existing conditions, identifying potential groups and/or departments for preliminary TPEM implementation, setting targets and predicting results;
6. Formulate TPEM organization-wide development and implementation plan;

Implementation stage:

7. Preliminarily implement TPEM on selected groups and/or departments; assess preliminary results; spread good experiences to other groups; build-up on good strategies and improve/avoid weak ones;
8. Develop an energy management program based on employees involvement, set productivity measures, dedicate responsibilities, and establish accountability;
9. Improve energy effectiveness of energy consuming equipment and systems in the facility;
10. Set equipment/systems energy efficiency as an operation and maintenance criterion and as an integral part of the scheduled maintenance program activities;
11. Conduct education and training programs to raise energy awareness, and improve operation and maintenance personnel and end users energy effectiveness skills;
12. Evaluate results and announce achievements;
13. Motivate O&M personnel, employees and end users and seek their feedback;
14. Implement TPEM fully, increase TPEM levels, and set higher targets.

It is important to recognize that employee motivation for active participation in the program is a major ingredient to TPEM. Therefore, lack of motivation can be damaging and can cause a failure to the program. Ignorance of employee contributions to solving the energy problem, lack of management support, lack of funds to improve operation and maintenance issues are some examples of problems that could reduce employee motivation. Possible means of motivation are discussed further in the following section.

Means of Motivation

In order to be able to achieve the objectives of TPEM, the people involved should be motivated. As most of these measures are behavioral-based, they cannot be achieved without proper motivation. The following are means of motivation:

- Commitment from top management: set examples (role model) for energy conservation efforts from upper management
- Understand the psychology of employees to know how to motivate them manage the energy resources effectively
- Relate to the principles of saving natural resources
- Relate conservation to human well being, health, environment, as well as economics
- Dedicate responsibilities for certain actions at certain times
- Hold every individual or group of individuals accountable for the management of energy systems in their area of work (equipment operation and maintenance, lighting management, daylighting, natural ventilation, etc.)
- Provide incentives to satisfy employees needs (financial and social); financial rewards in proportion to savings and increments of income; social recognition through awards, employee of the month, public recognition, etc.
- Conduct continuous in-house and outside training for employees; energy management training helps employees make informed decisions and recommendations related to energy operation costs [5: p.2]; training can also help improve motivation indirectly as a mean of recognition for being selected or nominated for certain training courses

- Solicit employee ideas for more efficient use of energy
- Respond to these ideas and never ignore them
- Establish TPEM prizes (annual) on the organization level as well as the national level

CONCLUSIONS

The concept of total productive energy management has been introduced. TPEM aims at involving employees in all levels of an organization in effectively operating the energy systems of the facility they occupy. TPEM will help implant the seeds of energy awareness and effective management of energy resource habits in employees who are part of families that constitute a society, resulting in a long-term effect on that society. The habit of effective management of energy systems by all individuals will be reflected not only in the facility they work at, but will extend to the home or other facilities which in turn will be reflected in the behavior of the society in the long term. Examples of such behavioral measures include switching off/reporting on equipment when not in use, switching off/reporting on lights when not needed and utilizing natural light and ventilation when possible.

Energy savings through day-to-day wise use/operation and maintenance practices can be successfully achieved and more feasible to implement than those achieved through major retrofits. However, it receives the least attention, is considered the least attractive and difficult to quantify. These negative attitudes can be overcome through the implementation of TPEM by involving all concerned in daily use/operation and maintenance of the facility. Further research and investigations on the implementation of such an approach needs to be conducted and savings to be quantified for an appreciation of its effectiveness.

ACKNOWLEDGMENT

The author would like to thank King Fahd University of Petroleum & Minerals for the support and facilities that made this research possible. Special thanks go to Dr. Ismail Budaiwi and Dr. Adel Abdou of the Architectural Engineering Department for their insightful review of the paper.

REFERENCES

1. Goetsch, David L. and Stanley B. Davis. 2nd Ed. 1997. Introduction to Total Quality: Quality Management for Production, Processing and services. Prentice-Hall, Inc. N. J., USA.

2. Hartmann, Edward. Editor. 1987. *Maintenance Management*. Ikuta, Seizo and Seiichi Nakajima. 'Total Productive Maintenance in Japan'. Industrial Engineering and Management Press.

3. American Society of Heating, Refrigerating and Air Conditioning Engineers. 1999. *ASHRAE Applications Handbook*. Atlanta, GA.

4. Kennedy, William J. and Wayne C. Turner. 1984. *Energy Management*. Prentice-Hall, Inc., Englewood Cliffs, N. J., USA.

5. Turner, C. Wayne, Editor. 3rd Ed. 1997. *Energy Management Handbook*. Third Edition, The Fairmont press, Inc., Lilburn, GA.

6. Mazzo, Martin A. 1998. Environmental Benefits from Energy Projects. Energy Engineering, Vol. 95, No. 3, pp 72-78.

7. Eibes, Timothy J. and Allen Jedlicka. 1984. Motivation: A Soft Approach to Energy Management. Heating/Piping/Air-conditioning, Sep., pp 91-97.

8. Nakajima, Seiichi. 1988. *Introduction to Total Productive Maintenance*. Productivity Press, Cambridge, MA, USA.

9. Schliesing, J. Steven, et. al. 1993. Building Operation: Opportunities for Improvement. ASHRAE Journal, Vol. 35, No. 11, pp. 38-43.

10. Jedlicka, Allen and Timothy J. Eibes. 1987. Team Approach to Energy Conservation. Heating/Piping/Air-conditioning, Sept., pp 91-95.

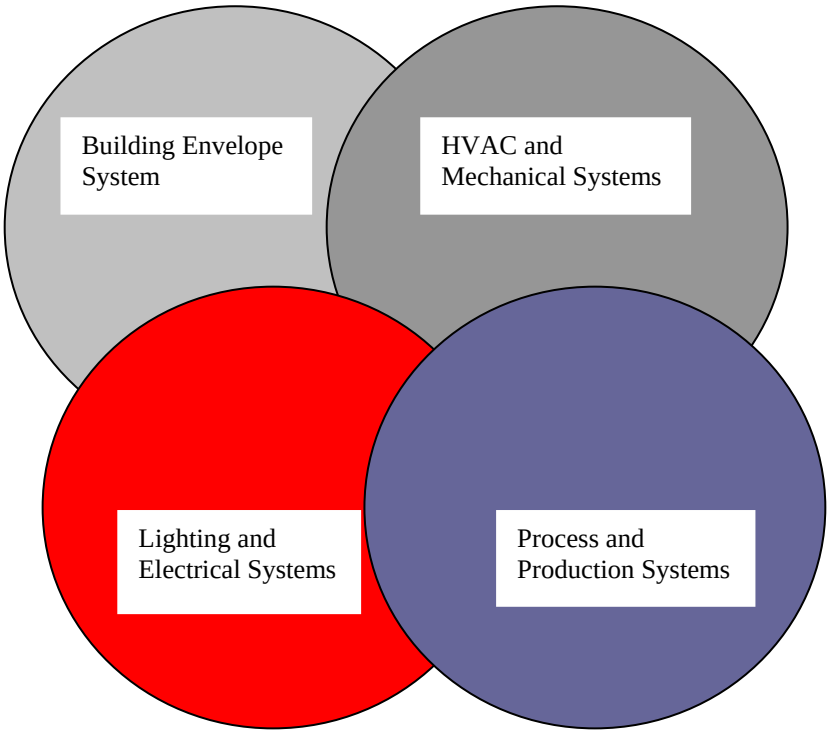

Figure 1: Interaction of Facility Energy Systems

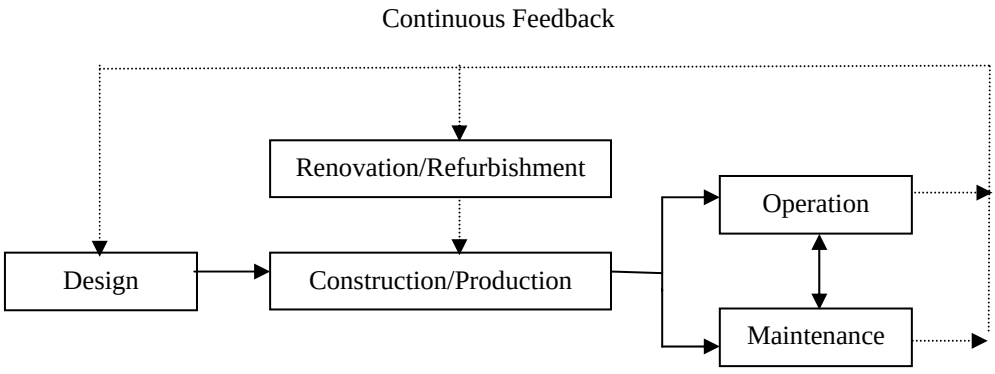

Figure 2: Facility/Production Life Process and Feedback

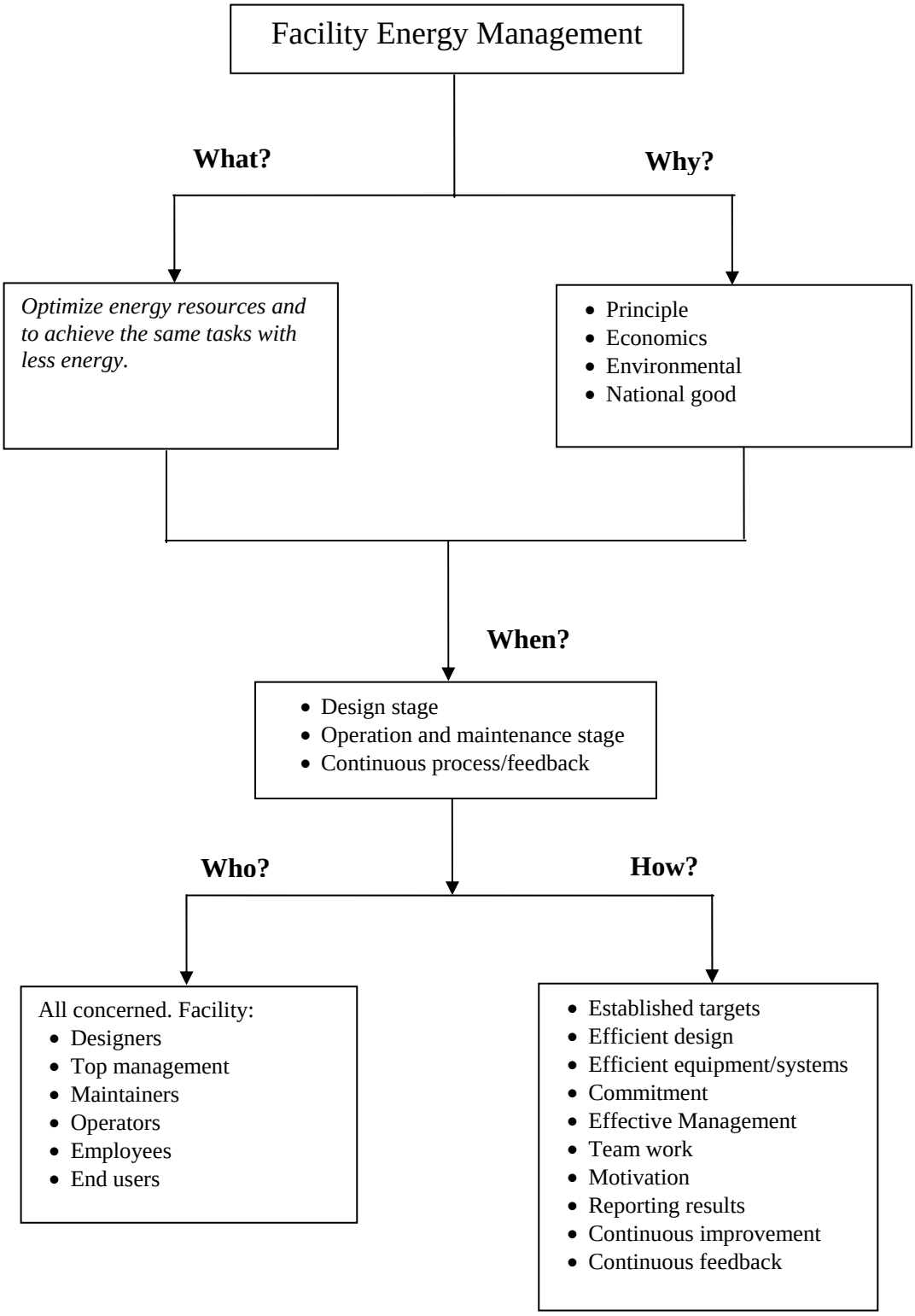

Figure 3: Facility Energy Management: Questions of Concern