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The Industrial Engineer and Energy and Environment

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ABSTRACT

Industries have always been a major consumer of energy and a major source of greenhouse gas emissions, causing environmental problems. Concerns about the impact of industries on the environment have led industries to change or adapt their methodologies to be more efficient and environmentally responsible. This article explains the impact that has on the industrial engineer.

KEYWORDS

Environmental Impact, Greenhouse Gas Emissions, Energy Efficiency, Energy Management, Life Cycle Assessment

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I . Introduction

Greenhouse gas emissions into the atmosphere result in global warming, leading to a change in climate and ecological systems. For this reason, there has been a binding international treatise for the reduction of the emission of such gases known as the Kyoto Protocol since 1997. 10 years later, environment at problems have become an issue that requires the responsibility of both state and private concerns to fix. Especially as The Fourth Assessment Report (AR 4), produced by the IPCC (Intergovernmental Panel on Climate Change), has indicated the disasters that could happen in various parts of the world, if there are no effective measures leading to the reduction of greenhouse gas emissions.

Research into the sources of greenhouses gases has found that industry is a major source of emitted gases. Fig. 1 shows the emission of greenhouses gases from various sources. [1]

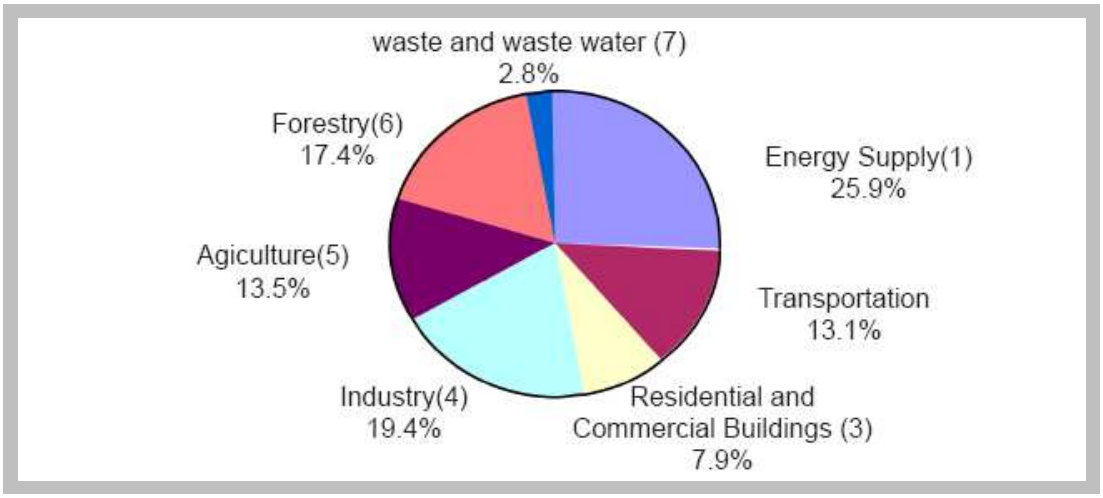

Figure 1
Greenhouse gases emitted from various sources in 2004

Notes

1) Excluding refineries etc., which are included under industry
2) Including international transport, excluding fisheries or transport used for agriculture or forestry
3) Including tradition usage of biomass
4) Including refineries
5) Including the burning of agricultural waste and fields, but not including the CO_2 from the fields
6) Including emissions from deforestation, decomposition of biomass from deforestation, and peat fire along with decomposition of dry peat
7) Including methane from polluted water and landfills, and nitrous oxide and carbon dioxide from waste incineration

The greenhouse gases that result from industries are the result of various manufacturing processes and the consumption of energy. The Kyoto Protocol has given the countries listed in its 1st appendix the responsibility to reduce their emissions of gases in line with the treatise, as well as the burden to search for methods to reduce such emissions, for which the main approach to reduction is increasing production and energy efficiency. The awareness of the issues of climate change resulting from greenhouse gas emissions has also raised awareness of other environmental issues.

Besides the additional burden of environment responsibility, industries also face energy problems: being a major source of emitted greenhouse gases and the increase in energy prices, both of which have resulted in an increase to production costs. Traditionally, when one talks of production cost, it refers to the cost of materials, labor and overhead, with energy and environmental costs included in the overhead, because most industries do not have a significant portion of these costs in comparison with the other two parts. However, as energy and environmental problems have become a global issue, these two costs will significantly impact production costs, and the survival of industries.

For the industrial engineer, any changes that impact industrial operations have to be studied and devised so as to minimize the problems that it would cause to industries. Such changes may also have to be researched to find a way to implement them to the industries' benefit.

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II. Energy Consumption in industry

The energy consumed in industries comes from electricity and fuel, by way of various kinds of energy-consuming equipment. The usage of electricity may be achieved through equipment that changes electricity into mechanical energy such as electric motors, into light such as light bulbs, into heat and cold such as air conditioning, into pressure such as air compressors, etc. The usage of fuel may be achieved through equipment that changes the heat from fuel combustion into steam energy, or uses the heat to fabricate various materials etc. The procurement and usage of such equipment requires consideration to both performance and energy efficiency.

In order to determine the plant layout, besides consideration for effective movement of production, also requires consideration of where to place energy-consuming equipment, as many types of equipment require a cool and well-ventilated installation. For example, air compressors should be placed so that the air intake is not too hot, as hot air takes more energy to compress; similarly, the condensing unit of air conditioning should not be where there is sunlight or lack of ventilation. Besides the already mentioned equipment, the industrial engineer should also consult with the engineers taking care of the equipment on the best place to install the equipment, for the benefit of energy efficiency.

Currently, various kinds of industrial production equipment have been developed for improved energy efficiency, but at a higher cost. Therefore, equipment selection requires consideration of the equipment's life cycle cost, resulting in the comparison of the total cost of using the equipment, not just the price.

Also, equipment selection should be at the capacity that will allow the operation at its full performance so that it will result in both production and energy efficiency. Production equipment always has some energy loss, so using the equipment to its full capacity minimizes said loss.

Planning the production, besides planning and controlling to produce at the customer required quantity and quality, also requires consideration of costs to save money, especially electricity rates that differ depending on the time of usage. For example, using the Provincial Electricity Authority's Time of Use Rate (TOU) for 69 kV upwards, the time of usage specifications are thus:

Peak	:	9:00 am – 10:00 pm Mon-Fri, and Royal Ploughing Day
Off Peak	:	10:00 pm - 9:00 am Mon-Fri, and Royal Ploughing Day
	:	All day weekends, Labor Day and regular holidays (not including observed days for holidays that fall on the weekend)

Peak electricity rates are 2.6136 THB/unit, while Off Peak rates are 1.1726 THB/unit. Therefore, production that can be done during Off Peak periods can reduce electricity costs, but possibly at the cost of overtime pay for labor.

Equipment maintenance is another major factor in the retaining of production and energy efficiency. Proper care of equipment is therefore required in a maintenance plan. During maintenance, there should be an inspection of energy efficiency, for the proper consideration of the equipment's viability and for planning to replace the equipment when its production ceases to be financially viable. Also, the higher energy prices the higher the production costs, so changing the type of energy/fuel may be an option to reduce production costs, but it also requires consideration to the effect on the environment. For example, the increase in petroleum costs has resulted in an increase in fuel oil costs, so changing to much lower-cost coal, despite requiring equipment replacement, is a worthwhile investment. However, such change results in more greenhouse gases being emitted, as well as fly ash from burning coal that needs to be removed.

When considering reduction of production costs, one needs to know where costs come from. This is also the case with reducing energy costs. How high or low these costs are depends on 3 factors:

- Production level: Higher quantities of production require more energy.
- Product mix: A factory may produce not just one type of product. Different production quantities of each product given time results in different energy usage.
- Specific Energy Consumption (SEC): Each type of product has a different SEC (measured in energy consumption per product unit).

From these three factors, it becomes apparent that the factor that has to be analyzed to find a way to reduce energy consumption is products' SEC values, which are variable due to production and energy efficiency. Therefore, increasing production and energy efficiency will reduce products' SEC values resulting in reduction of energy costs, given a constant product mix and production level. Analyzing the products' SEC values may use the same principles as product cost analysis.

To evaluate the Energy Efficiency of industry, one utilizes its Energy Intensity, which may be calculated thus:

$$\mathbf{EI} = \frac{\textbf{Input Energy}}{\textbf{Production Quantity}}$$

This value indicates the amount of energy used per product unit. This value may be similar to SEC, the difference being that EI in this case is the average SEC of all products, which may have different values at any given time, because of different product mix.

$$\mathbf{EI} = \frac{\textbf{Input Energy}}{\textbf{Production Value}}$$

This value indicates the energy usage per value of production.

$$\mathbf{EI} = \frac{\textbf{Input Energy}}{\textbf{Value Added}}$$

Determining the EI may also use other financial indices for the divisor, for example, sales circulation or transportation costs etc. depending on which financial index the industry wants to compare energy usage (or value) with.

Because of rising energy costs, the industrial engineer has to adapt his operation method to increase production efficiency and reduce production costs. Also, the depletion of reserve fossil fuels may become a major national problem. The Ministry of Energy has therefore passed laws and ordinances that require industries to look after energy consumption and energy saving. Most recently, the Ministry of Energy has amended the Energy Conservation Promotion Act of 2007, requiring controlled factories and buildings (defined as having a transformer of more than 1175 kV-A) to have an energy management system.

The energy management system that the Ministry of Energy has defined has a similar structure (Fig.2) to ISO9000, ISO14001 etc. management standards, making it simple for the industrial engineer to understand, as the system principles follow the PDCA cycle (Plan, Do, Check, Action).

Creating an energy management system may not seem difficult, but since industries already have many management standards, a new standard creates more cost. Therefore, to help the implementation of various management standards (ISO 9000, 14000, GMP, HACCP, TPS etc.) consume the least staff time and cost, there should be a combination of all specifications from each standard, so that shareable documentation and inspections can be prepared. Also, it should be organized into an industrial system for ease of use and convenience in audit reporting for each standard.

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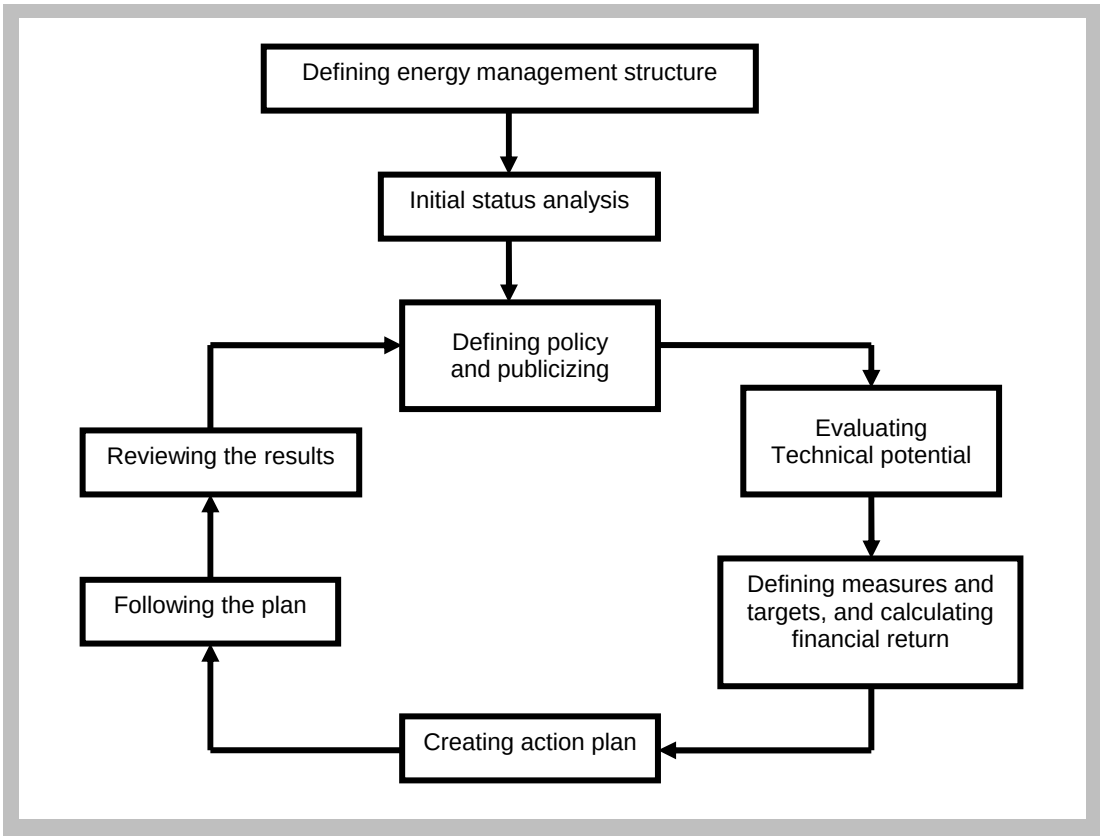

Figure 2
The process of developing an energy management system.

III. Environmental Impact

The problem of greenhouse gas emissions, resulting in global warming and leading to climate and ecological change, has resulted in the definition of various standards to reduce such emissions, as well as an awareness to protect the environment. Industrial operations and production have been eyed as a major source of various environmental problems. There have been campaigns to use environmentally friendly products in various countries. The countries listed in the 1st appendix of the Kyoto Protocol share the responsibility of reducing greenhouse gas emissions with industry. Such environmental awareness may result in trade restrictions in the future. Finding an approach for industries to reduce their effects on the environment may help reduce this threat, and may even be used as an investment opportunity.

As a result of being eyed as a major source of environmental and ecological problems, standards for environmental management have been defined for the industries to follow, such as ISO14000. This standard, besides ISO14001, the widely used standard for management systems, also incorporates standards for Life Cycle Assessment (LCA) for products and production processes, as well as standards for Environmental Labeling (EL) to indicate environmentally friendly products.

Life Cycle Assessment requires the industry to analyze and evaluate the effects of a product on the environment for the whole life cycle of the product, from acquisition of raw materials, production, transportation and sale, usage, recycling, and disposing of the product, by indicating the quantity of energy and raw materials consumed, as well as the waste emitted to the environment and its effects. This is in order to lead to the improvement of products to be more environmentally friendly. LCA has been proposed at the ISO/TC 207 meeting in The People's Republic of China in June 2007 (http://www.tisi.go.th) to be used as part of industrial standards. Also, LCA allows the public to find out the various environmental impacts of a product, leading to various regulations for importing products and regulations that require producers to recall expired products etc.

It becomes apparent that environmental development requires industry to bear more responsibility on the environment. Without proper preparation, it means higher production costs and smaller markets, due to limitations from environmental regulations. In 1991, the Business Council For Sustainable Development, now the World Business Council For

Sustainable Development (WBCSD), proposed that sustainable development for business should lead to "eco-efficiency", meaning ecological and economical efficiency, that is, the capability of delivering products and services to satisfy human needs for quality of living at a competitive price, while at the same time reducing the impact on the ecological system and the amount of natural resources consumed during the product's life cycle to a level that the earth can sustain. In short, eco-efficiency is about adding value to products and services while reducing their impact.

The WBCSD has defined 7 components for businesses to use in improving their eco-efficiency :[2]

- Reducing material intensity: reducing the amount of material per product unit or service
- Reducing energy intensity: reducing the amount of energy consumed per product unit or service
- Reducing the dispersion of poisonous substances
- Increasing recyclability
- Utilizing renewable resources as much as possible
- Increasing product durability
- Increasing service intensity: increasing the value of products or services, perhaps by making the product or service more beneficial to the customer, such as increasing the capability of using the product, providing supplementary services etc.

For measuring eco-efficiency, the WBCSD has defined this equation for calculating [3] :

$$\mathbf{E} = \mathbf{PV} / \mathbf{EF}$$

Where E = Eco-efficiency
PV = Product or Service Value
EF = Environmental Influence

Estimation for PV may be defined as

- Amount of product or service delivered to customers
- Net sales

Estimation for EF comes from

- Energy consumption
- Material consumption
- Water consumption
- Greenhouse gas emissions
- Ozone depleting substance emissions

For the development of eco-efficiency, the WBCSD has proposed that industries should look for development opportunities in 4 areas:

- Re-engineering the production process, leading to a production that consumes fewer resources, produces less pollution, reduces risk, and lowers cost.
- Re-valorize by-products, as the waste from one industry may be used as the raw materials for another. Selling or exchanging them may lead to the reduction of industrial waste.
- Re-design products to be more environmentally friendly, e.g., consider using raw materials that can be recycled, increasing its strength to be more durable etc.
- Re-think the market to find ways to satisfy customers without impacting the environment, e.g., providing a repair service instead of selling new products to replace old products.

IV. The Industrial Engineer and Energy and Environment

Previously, the industrial engineer may have been responsible for production efficiency. Currently, the involvement between production and energy and environment has inevitably pushed the industrial engineer into having to understand energy efficiency and eco-efficiency,

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which has to be combined into production. Requiring the combination of all three efficiencies widens the field of research in industrial engineering.

Besides responsibility to the three efficiency measures, the industrial engineer should also have a duty to create a system that helps following various standards and regulations from state and trade partners be achieved efficiently, that is, using the least time and cost, while still fulfilling the standards and regulations. Currently, many industries have various standards, and having to follow each standard's regulations separately wastes expenses.

As a supervisor of production resources, it is the industrial engineer's duty to study and to direct towards solutions to various problems that may result from using those resources, because in the end, the sustainability of industry is dependent on the industrial engineer's ability to adapt to various states of industry.

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