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# Life Cycle Analysis of Hazardous Waste from the Energy Conservation Measures in Existing Buildings

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## Abstract
The budget used for the retrofitting of low energy efficiency equipment in building is normally paid by financially considering the internal rate of return and a simple payback period. The environmental view has not been considered typically. One of the overlooked aspects within the energy conservation measures is the managerial cost of hazardous waste from the removed low energy efficiency equipment. LCA (Life Cycle Cost Analysis) is an approach to consider all inventories and impacts, including the costs in the case of LCC (Life Cycle Cost), covering the environmental aspect, particularly hazardous waste, throughout the life cycle from raw material preparation, removal of existing equipment, installation, to the waste disposal. This study will take into account only Hg in fluorescent tubes and CFC in air conditioners as representative of the range of wastes, because it can be emitted during the retrofitting. The LCA result is used for the creation of a conceptual decision making model showing clear components and structures of investment in retrofitting. The preliminary target audiences for this study are almost 1,700 designated buildings (defined in the Royal Decree; containing an installed transformer of more than 1,000 kW or 1,175 kVA annually or consuming energy more than 20 million MJ since 1995-2004) in Thailand.
**Keywords:** Hazardous waste; energy conservation measures; life cycle analysis

## 1. Introduction
Environment and energy issues around the world are getting more and more attention. It is necessary for the government in each country to increase its role in stimulating the awareness of these issues. If we consider the sustainable development as the definition by Norwegian Prime Minister Gro Harlem Bruntland which is to meet the needs of the present without compromising the ability of future generations to meet their own needs, the integration of energy and environment has to be done by the merging of energy conservations, renewable energies, and pollution preventions. One important area of the integrations is the hazardous waste from the energy conservation measures in existing buildings. There are certain sources of hazardous waste in the energy conservation measures that are applied in existing buildings. It is very important in the balance between energy savings and implementation cost plus the implicit cost of hazardous waste management. The approach of LCA on the energy conservation measures can be used to identify the phases or materials which show the major environmental impact. To reduce the hazardous waste at source, a preliminary conceptual model, created from the factors related major impact, can be used before the implementation of the energy conservation measures. [1]

## 2. Energy Conservation in Existing Buildings in Thailand
In Thailand, the Energy Conservation Commission in Thailand was started officially by the ENCON Act (Energy Conservation Act) of 1992 and the establishment of the ENCON Fund (Energy Conservation Promotion Fund) for relevant activities in the energy conservation area. Article 24 of the ENCON Act stipulates that the capital and assets of the ENCON Fund must come from two main sources. The first being money transferred from the Petroleum Fund at an amount determined by the Prime Minister. The second part comes from the levies imposed on petroleum product producers and importers at a rate determined by the NEPC (National Energy Policy Council). Additional sources are surcharges on power consumption, government subsidies at times, remittances from the private sector in the country and abroad, and the interest incurred from the ENCON Fund. The ECP (Energy Conservation Program) incorporating a Compulsory, Voluntary, and Complementary Plan are used as the key instrument in implementing energy conservation projects. [2]

The compulsory program enacted under the Royal Decree of Designated Building and Factory 1995 defines designated buildings (DBs) as buildings under the same house number where the total capacity of the transformer installed is more than 1,000 kW / 1,175 kVA or the annual energy consumption total is more than 20 million MJ. The DBs have to conform to the Ministerial Regulation 1995, Numbers 1, 2, and 3 issued under the ENCON Act which specify the Energy

Regulation, Energy Audit, and Target and Plan respectively. Energy Regulation forces the designated buildings to comply with the Building Energy Code covering the requirement for three systems i.e. the Overall and Roof Thermal Transfer Value (OTTV and RTTV), the Lighting Power Density (LPD), and the efficiency of Air-conditioning systems. [3]

Energy conservation inside the buildings means one of the following measures.

- The reduction of heat from the sunlight that enters the building.
- The use of efficient air-conditioning, which includes maintaining the room temperature at an appropriate level.
- The use of energy–efficient construction materials and the demonstration of the qualities of such materials.
- The efficient use of light in the building.
- The use and installation of machinery, equipment and materials that contribute to energy conservation in the building.
- The use of operation control systems for machinery and equipment.

Other measures for energy conservation as prescribed in the Ministerial Regulations. [4]

At the end of the year 2003, there were 1,646 designated buildings in Thailand and approximately 40% complied with the OTTV and RTTV requirements. About 83% complied with the lighting power density and around 50% complied with the air-conditioning standard. It was found that the existing Building Energy Code creates the following problems. [5]

Energy conservation measures in existing buildings play an important role in the compulsory plan within the energy conservation plan of Thailand and will be supported as a strategy of Thai Energy Development. [6]

The DANIDA (Danish International Development Assistance) has signed an agreement with DTEC (Department of Technical and Economic Cooperation of Thailand) to support technical assistance for the Adjustments to the Building Energy Code Project (ABEC) implemented by the Department of Alternative Energy Development and Efficiency (DEDE). The overall objective of this project is to reduce the energy consumption in designated buildings and the immediate objectives are to improve the codes, to increase the awareness and knowledge of the stakeholders, and to enhance the capacity of DEDE. [7]

The revised building energy code was prepared for a target group, namely the buildings that are going to be constructed (newly proposed) instead of existing building. This is the concept of "right at first", which is not to control the energy efficiency or consumption at the final stage of energy consumption. After the revised building energy code has been applied to the buildings to be constructed, the existing building energy code will be canceled. The existing buildings will lead to a voluntary incentive scheme. [8]

The history of energy conservation in the designated building sector implies that the building owners have to more or less apply the energy conservation measures into the buildings. Within the design phase or construction phase up to the operating period, the energy aspect is usually a key factor in performance assessment. [9]

The designated buildings that are going to be constructed require the approval or compliance with the Building Control Ministerial Regulations, where most of the environmental issues are related to the treatment of wastewater and garbage, air, noise, and other non-hazardous waste. [10]

New buildings, however, can apply the concept of energy conservation and environment during the design phase; whereas, the existing buildings can only apply retrofitting of energy conservation measures. Almost all of the measures are only concerned with the energy efficiency issues and forget to pay attention to other parts of the environment. From the investment perspective, there is a lot spent in the field of energy conservation measures in existing buildings. Between the years 2002 to 2006 the estimated subsidy and non-subsidy investment in energy conservation measures in designated buildings is expected to be around 3,165.51 million baht. Many energy conservation activities in existing building projects claimed that the environmental issue has been already addressed by converting the energy saving into the Carbon Dioxide reduction (the avoided cost of 1 MW of electricity is 45 mil baht, 1 GWh electricity generated produces 660 ton of Carbon Dioxide, and a Carbon Dioxide reduction of 1 ton costs 8,000 baht). [11]

### 3. Hazardous Wastes from the Energy Conservation in Existing Buildings

Hazardous wastes by the definition of the Resource Conservation Recovery Act of USA means a solid waste or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may cause or significantly contribute to a increase in mortality or an increase in serious irreversible, or incapacititating reversible, illness or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed. The meaning is not different from the Act of Hazardous Material 2535 by the Department of Industrial Work, Thailand which defines the hazardous wastes as the flammable, oxidize and peroxide, toxic, disease, radioactive, mutate, corrosive, irritate, hazardous to plant, property, or environment. [12]

The preliminary equipments in the energy conservation measures in the Specification of Energy Efficient Product 2000, by the Department of Energy Development and Promotion, are fluorescent lighting fixtures, lighting reflectors, compact fluorescent lamps, tubular fluorescent lamps, electronic ballasts, low loss ballasts, small air conditioners, electronic thermostats, heating or cooling surface insulation, heating reflective insulation, and voltage regulators. These equipments were use in the implementation of the energy conservation in the existing buildings. From the review of the database of the Department Alternative Energy Development and Efficiency, about 366 types of the energy efficient measures can be classified into 4 groups of measures i.e. Energy Management, Energy Efficiency Improvement, Retrofitting (Remove the existing and replace with the new one), and New Installation. The energy conservation equipments in existing buildings that relate to hazardous materials are mercury, lead, cadmium, sodium, and radioactive materials in fluorescent lamps, CFC in air-conditioners, $H_2N_2O$ (Nitrosamine) in closed cell insulations for piping, Zn in luminary reflector, and PCBs (Polychlorinated Biphenyls) or DEHP (Di-Ethyl Hexyl Phthalate), which are classified by the EPA as a probable human carcinogen in ballasts or HIDs (Hi Intensity Discharge Lamps). [13]

The retrofitting is the type of measures which emit the hazardous waste during the implementation. Mercury in fluorescent lamps and CFC from air-conditioner are the major and serious problem in environmental issues.
From the Guideline of the Used Fluorescent Lamp Management by Bureau of Hazardous Waste Management, the Department of Pollution Control Department, the amount of used fluorescent lamp in Thailand is about 41 million lamps in 2004 which is the straight tube 70%. From the view of sources, 66.4 % is from residential sector, 32.2 % is from big buildings, and 1.4 % from transportation services. The cost (refered from Japan experience) of a straight tube recycle plant is about 50 million Baht at the capacity 6 million tubes per year with the operating cost 1 Baht/lamp. Regarding the collection system, there is no official collection system of the fluorescent lamp or even some direct regulation. [14]

For the situation of CFC in Thai industry, under the Act of Factory B.E. 2535, there is the Notification of Ministry of Industry No.2 B.E. 2540; Ban of CFC in Household Refrigerator and the Notification of Ministry of Industry No.3 B.E. 2540; Ban of new factory producing spray contained CFC. The total CFC 11 and CFC 12 in Thailand is 3,462.06 metric Ton in year 2001 with the following distribution in the refrigerant sector. [1]

| | | |
|---|---|---|
| - Chiller CFC 11 | 130 | Ton |
| - Chiller CFC 12 | 15 | Ton |
| - Household refrigerator CFC 12 | 20.5 | Ton |
| - Commercial refrigerator CFC 12 | 66 | Ton |
| - Cold room & container CFC 12 | 39 | Ton |
| - Mobile air conditioning CFC 12 | 1,780 | Ton |
| Total | 2,050.5 | Ton |
| 59.2% from total in Thailand | | |

**4. Life Cycle Analysis (LCA) as a Tool in Impact Assessment of Hazardous Waste from the Energy Conservation Measures in Existing Buildings**

The environmental impact of energy utilization and hazardous waste from raw materials acquisition or research and development to the final disposition of a product and package has an effect on the quality of the environment. *One of the systematic approaches for identifying and evaluating opportunities to improve the environmental performance of industrial activity is termed Life Cycle Analysis (LCA).* There are three phases of LCA programs, i.e. inventory phase, impact or interpretation phase, and improvement phase. Life Cycle Inventory (LCI; ISO 14041) is the study of material and energy balance in process mapping within a boundary. Next are the steps of Life Cycle Impact Assessment (LCIA; ISO 14042) that deals with the following catergories and indicators.

- Global warming potential (Infrared radiation $W/m^2$)
  kg $CO_2$
- Ozone depletion (Stratospheric ozone breakdown
  kg CFC11
- Acidification (Deposition / Acidification Critical Load)
  kg $SO_2$
- Heavy metals
  kg Pb
- Summer smog
  kg $C_2H_4$
- Energy resource depletion
  MJ
- Eutrophication (Deposition/ N/P equivalents in biomes)
  kg $PO_4$
- Carcinogen substance
  kg Benzo $\propto$ Pyrene
- Photochemical oxidation (Troposphere $O_3$ formation)
  kg $O_3$/kg emission
- Human toxicity (Predicted Environmental Concentration / No Effect Concentration)
  kg 1,4 dichlorobenzene

Final steps are those of the Life Cycle Improvement Assessment (ISO 14043), which is to find opportunities to reduce the environmental impact of releases, energy, and raw material by assessing designs, materials, processes, consumer uses, and waste managements. [15]

About 1,646 existing designated buildings in Thailand is compulsory regulated under the Energy Conservation and Promotion (ENCON) Act 1992. The master plan of the Department of Alternative Energy Development and Efficiency (DEDE) expects to save about 1,442 mil kWh within 2002-2006 with budget 3,166 mil Baht. It can be assumed that the budget about 2.2 Baht is invested to save 1 kWh whereas 1.80 Baht/kWh generation cost from natural gas. It is cost effective if the awareness is increased. The budget is however not included the cost of hazardous waste management. The result of LCA and may change the decision making model for the energy conservation investment. The retrofitting may be the last priority or the energy efficient product designer has to redesign. In addition, the lesson learn from CFC & Hg can applied to other hazardous waste not only the sector of the energy efficiency but also the renewable energy e.g. Pb in batteries for solar cell. [11]

The scope of LCA of the hazardous waste from the energy conservation measures in existing buildings here is defined by the following terms.

- Functional unit; A kWh of saving from energy conservations
- Parameter; Air conditioner and fluorescent lamp
- Process; A retrofitting by replacing with high EE equipment
- Duration; 2002-2006 (master plan of energy conservation)
- Operation unit; A retrofitting in existing building
- Main function; save energy & prevent environmental pollution
- Sub-function; promote energy conservation awareness
- Reference flow; a 12000 Btu air-conditioner and 36 W FL
- Considered hazardous waste; CFC & Hg in energy conservation measures
- Initial System Boundary; the retrofitting in Thailand as figure 1.

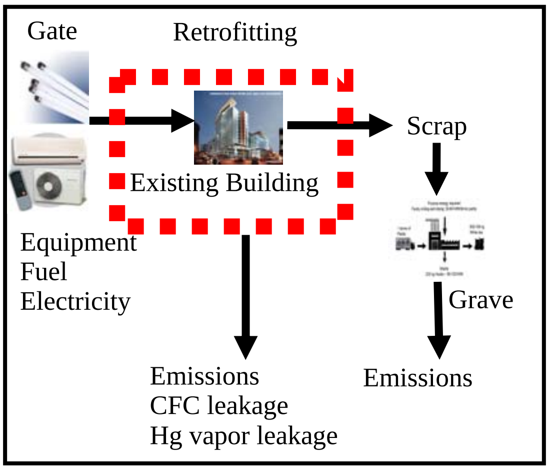


Figure 1 the initial system boundary of the LCA of hazardous waste from the energy conservation measures in existing buildings

**5. Existing Criteria Applied to the Evaluation of the Energy Conservation Measures**

The data of the retrofitting of fluorescent lamps and the air-conditioners in the Park Lane Mansion, the Dynasty Hotel, the office of Khet Huai Kwang (HK), the Bangkok Business College (BBC), and the discount store Tesco Lotus are shown in the table 1.

Table 1 Simple payback period (SPB) and economical investment rate of return (EIRR) of example buildings

| Buildings & Measures | Saving (kWh/yr) | Saving Value (Baht/yr) | Investment (Baht) | SPB (Yr) | EIRR (%) |
|---|---|---|---|---|---|
| Park Lane | | | | | |
| - FL | 447 | 1,269 | 1,634 | 1.29 | 77.21 |
| - AC | 204,560 | 782,440 | 1,830,000 | 2.34 | 44.05 |
| Dynasty | | | | | |
| - FL | - | - | - | - | - |
| - AC | - | - | - | - | - |
| HK | | | | | |
| - FL | - | - | - | - | - |
| - AC | 56,248 | 143,173 | 935,822 | 6.54 | 24.99 |
| BBC | | | | | |
| - FL | - | - | - | - | - |
| - AC | 175,701 | 458,935 | 4,030,200 | 8.80 | 8.56 |
| Tesco | | | | | |
| - FL | - | - | - | - | - |
| - AC | - | - | - | - | - |

FL means the retrofitting of the fluorescent lamp
AC means the retrofitting of the air conditioners
Source: One Stop Service, DEDE

Consideration by using IRR (Internal Rate of Return) or SPB (Simple Payback Period) without environmental disposal costs during the financial assessment of energy conservation retrofitting measures is one of the most obvious examples where the integration concept is needed. In the group of existing building, there is no significant integration of environment into the retrofitting energy conservation measures. The concept of adding the environmental aspect into the consideration of energy conservation streamline homogeneously will be called “Envirogy”

**6. Conclusion of the Preliminary Conceptual Model of Decision Making for the Energy Conservation Measures in Existing Buildings**

The concept of waste minimization requires the materials, technologies, products, workers, and processes to behave cooperatively as modeled in Figure 2. [16]

The created preliminary conceptual model is composed of all important factors of concern based on the relation and data from life cycle analysis; that is the energy saved, implementation cost, operational cost, maintenance cost, disposal cost, and implicit cost generated from the hazardous waste.

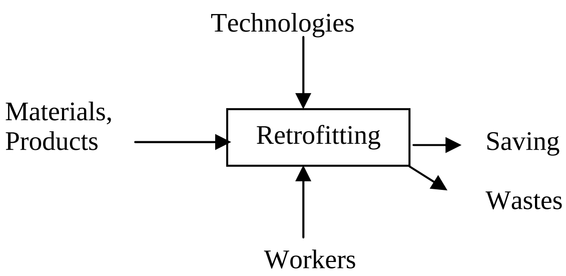


Figure 2: Preliminary Model of Waste Minimization

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