# Cleaner Production in the Plastic Industry of Ho Chi Minh City, Vietnam

**Nguyen Le Truong[*] and S. Kumar[**]**

[*] Energy Conservation Research and Development Center
273 Dien Bien Phu St., Dist. 3, Ho Chi Minh City
VIETNAM

[**] Energy Field of Study
School of Environment, Resources and Development
Asian Institute of Technology
P.O. Box 4, Klong Luang, Pathumthani 12120
THAILAND

*E-mail: kumar@ait.ac.th*

## ABSTRACT

*The plastic forming industry is an important industrial sector in Vietnam showing significant growth in recent years. Lack of trained manpower and inefficient use of resources in this sector indicate that the competitiveness of this sector may be affected. A cleaner production study carried out in Ho Chi Minh City in the plastic forming industries indicates that many options are available for reducing energy consumption and waste, and thus increasing profits. Details of the audits carried out and the results of implemented cleaner production options show that the options identified and implemented reduce energy use and pollution, and have very attractive pay-back periods.*

## 1. INTRODUCTION

The rubber and plastics industry is one of the fastest growing industries in Vietnam (Fig. 1). In Ho Chi Minh City (HCMC) alone, it is estimated that plastic factories employ more than 40,000 people, representing about 5.8% of the total industrial labor force of the city [1]. These industries generated a

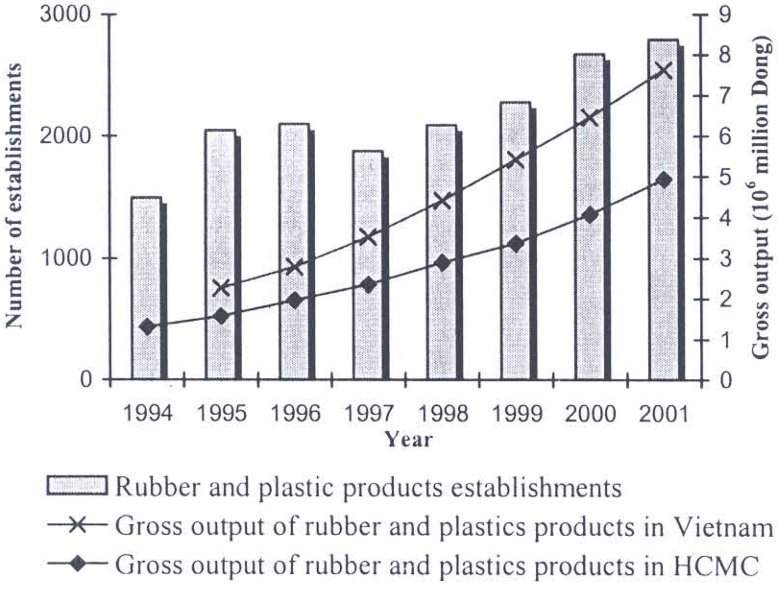


Fig. 1 Rubber and plastics industry in HCMC [2, 3]

gross output of 7,312 billion Dong (US$ 1 = Dong 14,000) in 2001 – approximately 7.1% of total gross output of industry in HCMC and about 65% of total gross output of plastic products of the whole country.

Plastic forming industries are resource intensive. Lack of knowledge about resource (energy and raw materials) conservation combined with the rapid growth in the production means that if adequate steps are not taken, this sector would consume a greater share of energy and materials, and also contribute to pollution and waste disposal problems. At the same time, information regarding energy use and pollution aspects from this industry are not well documented.

In this context, a study on cleaner production was initiated to assist plastic companies to:

- evaluate their current resource (energy, raw material, etc.) use and efficiency, and
- implement options for energy saving and pollution reduction/mitigation.

This paper summarizes the work done [4] to address the mentioned objectives and describes the methodology, activities carried out, and the results obtained. The general production process in a plastic forming industry is presented. The methodology used to carry out the audit, the observations noted and the proposed options are described. The options implemented and the results are also presented.

## 2. PLASTIC FORMING INDUSTRY

The plastic forming process is quite simple as shown in Fig. 2. The plastic material is first mixed with additives and then transferred to the hopper of molding machine. The molding machine can be injection molding, extrusion molding or extrusion blow molding. The products of this machine are then passed to finishing and packaging section. Each process during the production requires energy in various forms: electricity for mixing, heating, prime mover, finishing, and other processes; and compressed air to control the mold in injection molding machine, and to blow the parison in blow molding machine. Water is also required to cool the product, the mold and the hydraulic oil of injection molding machine. The energy source used in the plastic factories is electricity. In plastic product manufacturing process, there are four sources of pollution: pellet release, additive chemicals, wastewater, and fugitive emission.

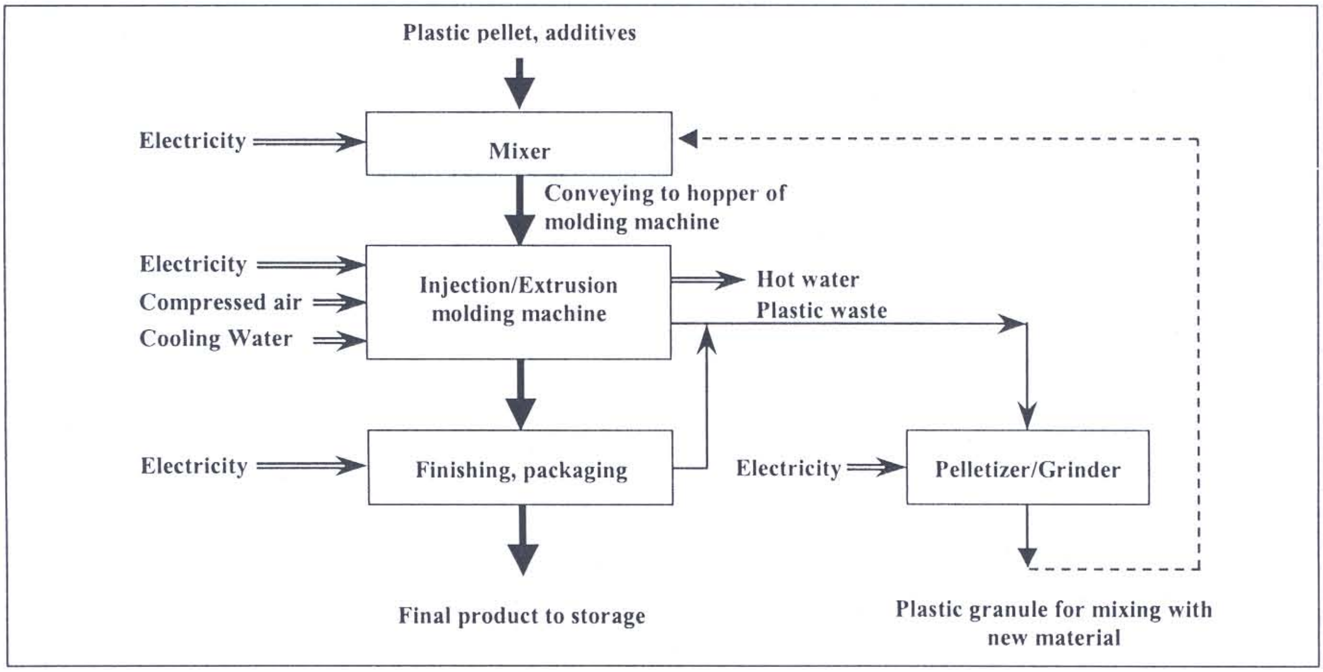


Fig. 2 General plastic forming process

- **Pellet release**: During transportation and while being loaded into molding machine, materials are sometimes lost to the floor. Although plastic pellets are considered inert, it is an environmental concern because of the harm they can cause if runoff carries them to wetlands, estuaries, or oceans where they may be ingested by seabirds and other marine species.
- **Additive chemical**: Additives are added to plastic pellets to alter and improve their basic chemical, mechanical and physical characteristics. Normally, the chemicals are added in such small amounts that most manufacturers do not consider them to be a problem; however, some of the additives could be toxic and therefore, even small amounts could present significant problems. This pollution can be in the form of spill during weighing, mixing and handling of chemicals; the remaining chemical in the containers and in the molding machine; or in the form of dust fugitive emission when it is exposed to the ambient.
- **Wastewater**: Water is used in plastic molding processes to cool (or heat) plastic products, and to clean the surface of both the plastic products and the production equipment. This wastewater may also be contaminated with oils, greases, organic compounds, and metals.
- **Fugitive emission**: During the molding process, when the plastic resin is heated and compressed, additives are vaporized and may be released to the ambient. The toxicity of these gases depends on the additives used [5].
- Besides the pollution emitted during processing, plastic waste is also an important concern in plastic forming process. However, this is usually recycled.

## 3. METHODOLOGY

The methodology adopted in carrying out the study is described in this section. An initial survey of plastic factories in Ho Chi Minh City was carried out to know the status of energy use and pollution generation in the factories. A seminar was arranged for the factory management, where cleaner production principles were explained, and the benefits that could be obtained by carrying out cleaner production audit were highlighted.

Three factories were then identified for an in-depth study based on the management's commitment and assistance from the Department of Science Technology and Environment of Ho Chi Minh City.

An audit was carried out in three factories, and based on the audit, cleaner production options for implementation were presented to the factories. Some of the options were then implemented in the factories.

Finally, a workshop was organized for the plastic factories and related agencies, where the results of the study were presented. The factories where the audits were conducted presented the results in order to convince other factories on the merits of carrying out cleaner production.

## 4. OBSERVATIONS

### 4.1 Initial Survey

The results of the initial survey of 19 plastic forming industries in HCMC indicated that in most factories, energy and environmental management is not considered seriously. Information about production, waste, and operating status of machines are not properly collected and analyzed.

#### *General Observations*

Some general observations from the survey were:

- Lack of suitable well-trained personnel in the management means that measures for reducing energy and pollution costs are not known or implemented. None of the factories surveyed had a designated person responsible for energy and pollution management.

- Injection molding and extrusion molding processes cover a large portion (89%) of the plastic forming industry.
- The raw (plastic) material covers a large portion of the total income, from 27% to 62%, while the energy cost covers about 3% to 17%. In some factories, the cost of purchased water can be 1% of the total income.

### *Energy*

The energy source used in the plastic factories is electricity. Most factories surveyed (79%) have a backup generator in case of shutdown from the power supply since plastic production is quite sensitive to power supply cut off. Other observations include:

- The price of power depends on time of use (three-price tariff). A study of the power consumption and electricity charge shows that the working ratio between day and night was similar in all months, regardless of production of that month.
- Some factories concerned about energy saving simply reduce the time of equipment use.
- In the extrusion-molding machines, heating is divided into two zones:
  - *Heating cylinder*: In this zone, heating (in the form of electric heating band) and cooling (in the form of air fan) are applied. The control includes supplying of heat when the temperature of the cylinder is lower than the minimum preset value, and removal of heat when the temperature of the cylinder is higher than the maximum preset value. The average temperature along this heating cylinder is 190°C to 200°C. This zone is put in a metal cover without any insulation.
  - *Die*: In this zone, the heating area is not insulated. Surface temperature of this zone is also very high, at around 210°C to 220°C.
- The present situation of heating system causes loss of energy (which is paid in the form of electricity bill). Moreover, the emission of heat to the ambient causes an increase in the ambient temperature, which inconveniences the workers nearby.

### *Cooling Water Systems*

Water is used for cooling the molds and hydraulic oil in the injection molding machines. Water is either purchased or pumped from deep well; therefore, cost of water is in the form of electricity cost for pumping system. It was observed that in many cases, the water pumping system was inefficient due to poor controls, mixing of hot and cold water before cooling in the cooling tower, and other factors. This, in effect, results in energy costs throughout the operation of the factory.

### *Compressed Air Systems*

Compressed air is used for controlling, closing/opening molds, cleaning, and other operations, and is obtained by using small reciprocating-type air compressors. These air compressors operate in an on/off regulation basis: when air system pressure falls below a pre-set lower pressure level, the compressor starts, and when air system pressure increases above a preset upper pressure level, it stops.

### *Pollution and Waste*

Preliminary studies indicated that there are some areas where the noise levels exceeded the limit, especially the grinding areas. In some locations near molding machines, the air temperature was high (above 40°C).

It was observed that the water used for cooling is generally recycled and so, there is no discharge of industrial wastewater. In other factories the wastewater is directly discharged, but in small quantities.

The solid wastes from the plastic factories are plastic waste and material containers. It was observed that plastic waste is classified and the factories had facilities for the recycle of waste.

In general, most of the savings are possible through reduction in energy consumption in the plastic factories.

## 4.2 Detailed Audit and Observations

Following the first workshop, three factories were selected for a detailed audit which indicated the following observations in the areas of energy use, prime mover system, cooling water systems, compressed air systems, and pollution and waste.

### *Energy Use*

- The specific energy consumption (SEC), calculated as the ratio of the energy consumed (kWh) per unit product (kg), varied from 0.6 to 1.7 kWh/kg of final product (Fig. 3). The average SEC of plastic factories is around 1.06 kWh/kg. For small-scale factories, the average SEC is 1.46 kWh/kg, while for medium and large scales, this value is only 1.0 kWh/kg. (The minimum SEC observed in a factory was 0.75 kWh/kg, when the monthly production was the highest).
- There is no significant difference in the SEC between injection and extrusion processes. The average SEC for injection process is about 1.05 kWh/kg while that of extrusion is 1.07kWh/kg.
- In general, the power factor of the plastic factories is low, from 0.4 to 0.7.
- The present situation of heating system causes loss of energy (which is paid in the form of electricity bill). Moreover, the emission of heat to the ambient causes an increase in the ambient temperature, which inconveniences the workers nearby. In one factory, all the heating barrels were exposed to ambient since the metal cover is damaged. Temperature measured along the barrel of PVC pipe machine was around 260°C.

The analysis indicates that there is a significant potential to reduce energy (electricity) consumption of the molding machines through appropriate insulation.

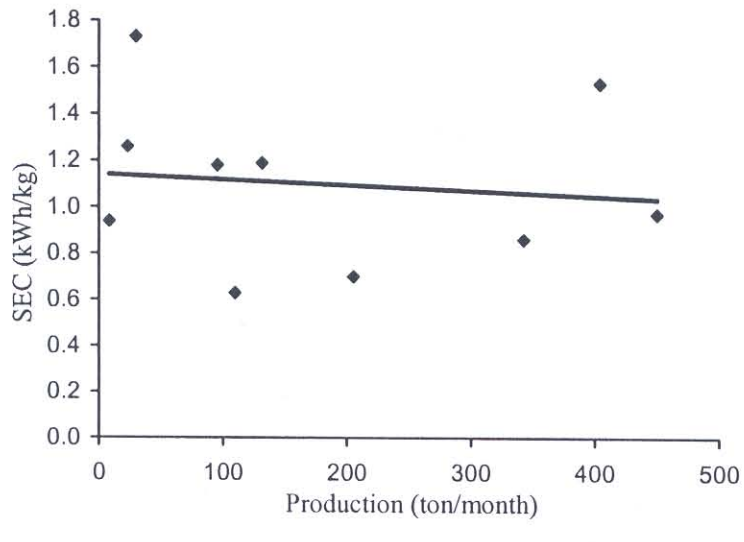


Fig. 3 Specific energy consumption vs. production in the plastic forming industry of Ho Chi Minh City

### *Prime Mover System*

The factory using injection molding process has no variable speed drive. In these machines, the rotation and motion of screw is controlled by hydraulic oil, which is pumped by electric motor. The flow rate of hydraulic oil is controlled by a by-pass valve which is inefficient. Most of the time, motor operates at part load.

In the case of extrusion molding machines, variable speed prime mover controls the flow of molten plastic leaving the die. Table 1 shows the status of variable speed (VS) coupling motors in one factory indicating the low load as compared to the capacity. Waste energy is discarded into the ambient in the form of heat. This causes an increase in energy bill and an increase in the ambient temperature. For this type of control, the higher the difference in the motor speed and the output speed, the higher is the power loss.

Prime movers for extrusion screws in a factory are supplied by motors through gearboxes. According to the measurements, all the motors are working at conditions far lower than their rated load. These motors operate at the load level of only from 39% to 19% rated load. This causes the low performance efficiency as well as lowering of power factor (which increases the losses in the power distribution network within the factory).

Table 1 Status of variable speed coupling motors

| No. | Parameter | Machine | | | |
|---|---|---|---|---|---|
| | | No.2 | No.3 | No.4 | No.5 |
| 1 | Capacity (HP) | 75 | 60 | 60 | 60 |
| 2 | Power consumption (kW) | - | 22 | 19.4 | - |
| 3 | Output rated speed range (rpm) | 1275-215 | 1200-120 | 1350-135 | 1350-135 |
| 4 | Set speed (rpm) | 700 | 320 | 560 | 1000 |

### *Cooling Water Systems*

Water used for cooling the molds is controlled using bypass valves. This control technique is inefficient. Moreover, the cold-by pass water is mixed with hot water and is pumped to cooling tower for cooling. This costs energy for pumps and fans in cooling tower and also reduces the cooling efficiency of cooling water.

A study of the performance of each separate system showed that the overall efficiency of each pump set is very low, only from 10% to 14%. All the pump's motors are working lower than rated load, from 31% to 75%. This shows that the design of system can be improved.

In one factory, the control system for the pump (on/off floating switch) has malfunctioned and therefore, pumping system works continuously. The surplus water is circulated through cooling water tower and discharges directly to the underground tank. Therefore, this system can be improved by simply repairing/replacing the control system for pump.

### *Compressed Air Systems*

The audit indicated the following observations:

- The actual demand is much less, and in some cases, only about 40% of total installed capacity.
- Compressed air is transferred through a long distance by small pipe. Therefore, pressure loss is high. In some places, compressed air has to pass about 100 m. length through a 1 cm-diameter pipe.

During the audit, these compressors were found to start and stop in a cycle of every 5 minutes.

- Compressed air is also used for controlling, closing/opening molds, cleaning, etc. Compressed air leakage was observed in joints between pipes and sections at thread making machines and the compressor has to start and stop every 2 minutes.

### *Pollution and Waste*

- **Noise:** Noise can cause discomfort and hearing loss to workers nearby. During the audit, noise level in each section of each factory was evaluated by sound level meter. A noise level of less than 90dB, working in a shift of 8 hour/day is considered to be safe [6, 7]. However, there are some areas where the noise levels exceeded this limit, especially at grinding area (101dB), weaving machine (> 90dB) and molding machine (93 to 94dB) areas.
- **Ambient air:** Ambient air affects directly the health and comfort of workers in the factory. During the detailed audit, parameters of ambient air collected were humidity and temperature. It was observed that the relative humidity at working place varies from 40% to 50%, while temperature varies from 35.5°C to 38°C, depending on the location. Particularly, in some locations near molding machine, temperature can reach 42°C to 45°C (ambient temperature was 35.5°C).
  There is also a concern regarding the use of kerosene in the printing section. Though measurements were not made, the concentration of VOC may be high.
- **Wastewater:** Two of the factories audited recycled the wastewater. In the third factory, cooling water is discharge directly to the community sewage system. Since this discharged water is from the cooling process, the temperature of this water is only around 35°C, and this is considered not harmful to the environment [8].
- **Solid waste:** Solid wastes are generally plastic waste, material containers, and in one factory wastes from printing processes (paint container, clout, rejected printing paper, etc.). The plastic waste is classified and fully recycled inside the factories, while the material containers are segregated and are partly used for storing the final product, and the rest sold. The hazardous wastes are containers of additives, paint, clout, and these are discharged together with domestic waste. This type of waste is not regularly produced and is of low quantity.

## 5. CLEANER PRODUCTION OPTIONS: IMPLEMENTATION AND RESULTS

Based on the observations during the audit in the three plastic forming factories, the following options were considered for implementation.

### 5.1 Insulation of the Heating Barrel

The energy (electricity) consumption is high, and is mainly consumed in the molding machines. As noted, the heating barrels are not insulated leading to loss of useful energy (heat) to the surroundings and increasing the temperature of the surrounding ambient conditions. Providing an insulation layer to the heating barrel will help to:

- reduce the heat loss from the heating band, and reduce the power consumption; and
- increase the safety for workers since surface temperature of insulated barrel will reduce to a safe level.

This option was studied and implemented in the three factories leading to significant savings in electricity consumption:

- Insulation of an injection molding machine and extrusion molding machine helped to save 2.2 kW and 2.3 kW in two machines which is about 7% and 32%, respectively of the total power consumption of these machines. The nearby ambient air temperature reduced from 33.6°C to 30.9°C.
- Insulation for one plastic thread making machine (extrusion) gave a 7.31 kW saving, equivalent to 12.8% of the total power consumption of this machine. The temperature near the machine (at the location 1 m far from the cylinder) reduced from 45°C to 40.5°C after providing insulation.

Figure 4 shows the electricity consumption profile in the three factories before and after insulation of the barrels. Table 2 summarizes the cost and benefits of this option. Based on these results, insulation of the heating barrels has been carried out for all the molding machines in two factories, while in the third factory, this option is under consideration for implementation in all the remaining molding machines.

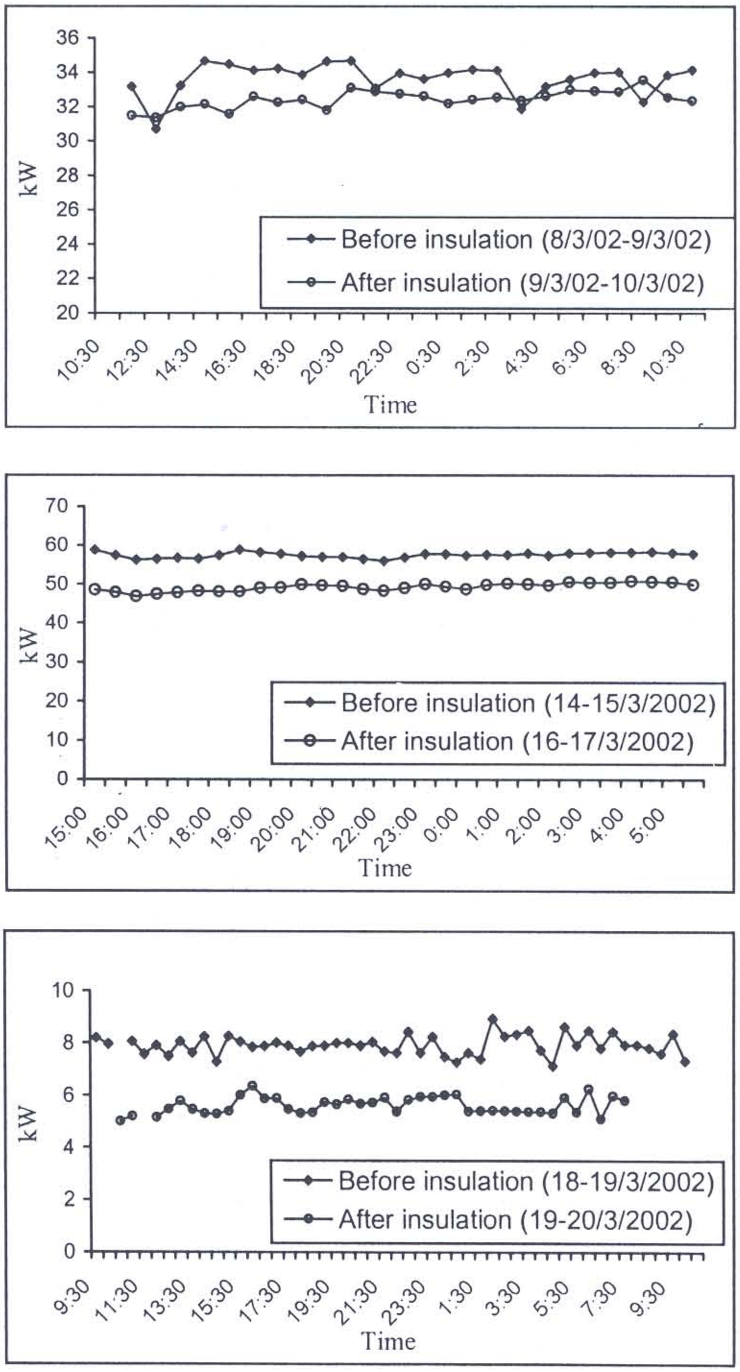


Fig. 4 Power consumption profile in three factories before and after insulation

Table 2 Cost-benefit of the insulation option in the three factories

| No. | Factory | Investment cost (Dong) | KW saving | % saving of machine | Saving (Dong/month) | Payback period |
|---|---|---|---|---|---|---|
| 1 | Factory A | 520,000 | 2.20 | 6.5 | 1,100,000 | 14 days |
| 2 | Factory B | 630,000 | 7.31 | 12.8 | 3,650,000 | 5 days |
| 3 | Factory C | 330,000 | 2.29 | 32 | 1,100,000 | 10 days |

## 5.2 Use of Variable Speed Drives

***Prime Mover***

The audit indicated the inefficient nature of the variable speed coupling in the prime mover resulting in increased power consumption and higher ambient temperature near the machine. The suggested option was, therefore, to replace the variable speed drives in place of variable speed coupling. This was applied in one molding machine, and by this replacement, the SEC of this machine decreased from 0.96 to 0.68 kWh/kg (reduction of 28%). A simple financial analysis indicated that the payback period is less than 5 months.

***Cooling Water Drives***

A new cooling water system has been proposed to replace the present system in one factory (Fig. 5), which will maintain the same pressure at the main distribution pipeline. A variable speed drive (VSD) is used to control the pump speed based on the pressure signal at main distribution pipe, detected by pressure transmitter. This option would reduce pipe work and space for pumps. Investment cost for pump is also reduced since the system requires only one pump (in place of many pumps for many systems), the flow rate can be changed/controlled depending on demand, and bypass mechanisms are eliminated thereby eliminating the energy losses.

The estimated saving from this option is about 19.5 kW (7.7 million Dong/month), equivalent to 85% of total power consumption for the present cooling water system. This option requires an investment of 77.6 million Dong. The payback period is 10 months.

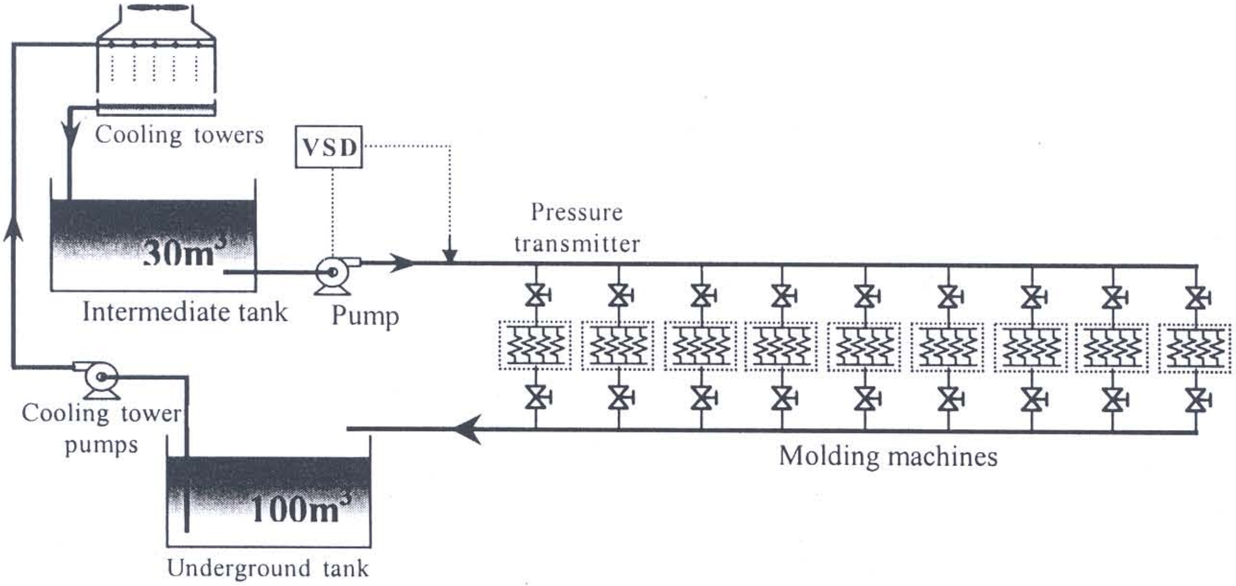


Fig. 5 Water system using adjustable speed drive

### 5.3 Replacing Low Load Motors by Suitable Ones

In one factory, motors transmit power through gearboxes to the extrusion screws. The motors were working at conditions far lower than their rated load, only from 39% to 19%. This results in low efficiency as well as lowering of power factor (which increases the losses in the power distribution network within the factory). Estimations made for the motor of PVC pipe making machine showed that by replacing this motor by a suitable one, power consumption can be reduced by 0.55 kW, which is 18% of total electricity consumption of the motor. At the present working condition, the yearly saving can reach 3.2 million Dong. Investment cost for such a motor is around 2 million Dong; therefore, the payback period for this replacement is around 7.6 months.

### 5.4 Improving Working Condition

In some certain areas in these factories, to control the noise problem, the following measures can be adopted:

- **Reducing noise at source**: Isolating the machines that produce loud noise and using sound absorbing material on walls and ceilings; regular maintenance of equipment, replacing worn bearings, increasing greases at bearing, and other measures.
- **Providing protective equipment to workers**: This should be the last option after considering other measures to reduce noise since ear masks are uncomfortable and could also cause ear infections. Moreover, workers equipped with ear masks cannot follow safety signals.

The comfort condition in these factories can be improved by increased ventilation. All the factories are equipped with industrial fan for artificial ventilation. According to Fairey [9], at air velocity of 1.5m/s (300 feet/min), and at humidity less than 50%, comfort temperature can be increased to 30°C (100°F). Therefore, care should be taken to provide good ventilation to improve the condition of working ambient. However, the best solution to improve this high temperature is to eliminate the source of heat to the ambient.

## 6. CONCLUSION

The plastic industry in Vietnam, particularly in HCMC, is expected to grow at a high rate because of the many applications of plastics. This growth would result in increased energy consumption and pollution. This study has demonstrated the many possibilities to reduce energy consumption in the plastic factories. Implementation of all the suggested CP options would also lead to improved working condition, reduced pollution and increased profits.

The savings attained by the work carried out in this study have been evaluated and summarized in Table 3. The results show that by introducing few energy conserving options, the total power (and so the energy bill) saving can range from 12% to 31%. The principal result has been in the reduction of specific electricity consumption, and Fig. 6 shows the changes in SEC before and after implementing the proposed options.

After the demonstration in the three factories, the option of insulating the barrel has been adopted by two factories, and insulation has been applied for all the remaining machines in these factories.

The option of changing from variable speed coupling to variable speed drive has been undertaken in one machine in the beginning stage (August 2002). The measurement before and after this renovation has proved that 28% (17.3kW) of electricity supplied to the machine has been saved. Due to the success of this demonstration, this factory is now replacing their remaining variable speed motors (up to now, two machines have been replaced).

Table 3 Total savings from the four suggested options

| No. | Option | Saving (kWh/year) | Saving (kW) | Saving (mil.Dong/yr) | Saving (%) |
|---|---|---|---|---|---|
| | ***Factory A*** | | | | |
| 1 | Insulation | 73,919 | - | 59.14 | 5.47 |
| 2 | VSD for water system | 115,711 | 19.4 | 92.57 | 8.56 |
| | *Total* | 189,630 | 19.4 | 151.71 | 14.03 |
| | ***Factory B*** | | | | |
| 3 | Insulation | 412,140 | - | 329.71 | 5.57 |
| 4 | VSD for prime mover | 460,889 | 49.4 | 368.71 | 6.2 |
| | *Total* | 873,029 | 49.4 | 698,42 | 11.77 |
| | ***Factory C*** | | | | |
| 5 | Insulation | 23,172 | - | 18.53 | 25.7 |
| 6 | Motor changing | 5,071 | 1.6 | 4.06 | 5.6 |
| | *Total* | 28.243 | 1.6 | 22.59 | 31.1 |

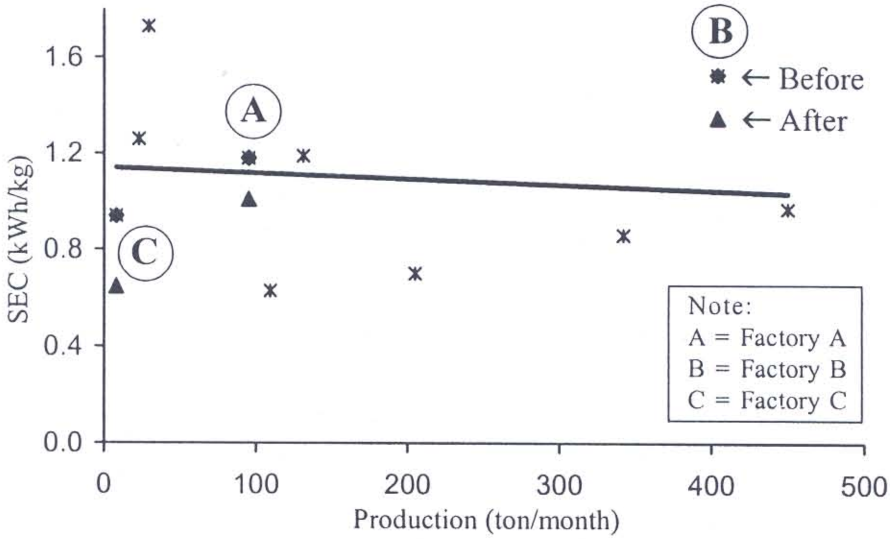


Fig. 6 Changes in SEC after implementing energy conservation options

During the dissemination seminar at the conclusion of the study, technology fact sheets were prepared based on these two options, and disseminated to the participants.

The opportunities for improving the present working condition and reducing operating costs could be as simple as regular maintenance to as complex as replacing the present system. Though energy cost covers a small portion of the total production expense, but unlike others, it is controllable.

Therefore, energy conservation is an option to reduce the production cost and to deal with (any future) increase in electricity price.

## 7. ACKNOWLEDGEMENTS

Nguyen Le Truong is grateful to the Government of France (Ministry of Foreign Affairs) for providing scholarship to study at AIT. The authors would like to thank the French Agency for Environment and Energy Management (ADEME), the Department of Science Technology and Environment (DOSTE) of Ho Chi Minh City and the management of the plastic factories for their assistance in carrying out the study. Thanks are also due to Dr. B. Mohanty and Prof. C. Visvanathan for their support and encouragement.


## 8. REFERENCES


[1] Trang, T.C.H.Q. 2001. *Vietnam – Asean Rubber Plastic Directory, 2000-200*. Ho Chi Minh City: HCMC Plastic Association, Vietnam.

[2] VN SYB (Vietnam Statistical Yearbook). 2000. National Statistical Publisher, Vietnam.

[3] HCMC SYB (Ho Chi Minh City Statistical Yearbook). 2000. Ho Chi Minh City: HCMC Statistical Publisher, Vietnam.

[4] Truong, N.L. 2002. Energy and Environment Management in the Plastic Forming Industry of Ho Chi Minh City, Vietnam. Master's Thesis ET 02-24, Asian Institute of Technology, Thailand.

[5] EPA (U.S. Environmental Protection Agency). 1995. EPA Office of Compliance Sector Notebook Project: Profile of the Rubber and Plastics Industry. US EPA Office of Compliance.

[6] AFE (American Federation Employees). 2002. Noise, Health and Safety – Fact Sheet, June 2002. <http://www.afscme.org/health/faq-nois.htm>

[7] ILO (International Labour Organization). 2002. Your health and safety at work - Noise at work June 2002. <http://www.itcilo.it/english/actrav/telearn/osh/noise/noiseat.htm>

[8] TCVN. 1995. *Vietnam Standard*. Ministry of Science, Technology and Environment, Vietnam.

[9] Fairey, P.W. 2002. *Passive Cooling and Human Comfort*, University of Florida, Cooperative Extension Service, Institute of Food and Agricultural Sciences, June 2002. <http://edis.ifas.ufl.edu/BODY_EH221>