

Development of energy benchmarking based on process consumption for the plastics industry in Vietnam

Duong Trung Kien, Do Thi Hiep^{a*}

Faculty of Industry and Energy Management, Electric Power University, 235 Hoang Quoc Viet, Ha Noi, Vietnam

Abstract

Plastics industry is one of the largest energy-consuming sectors in Vietnam. In this work, we propose and develop a methodology to formulate energy benchmarking for the industry. We investigate the energy benchmarking for three sub-sectors of plastics which comprise plastic packaging (plastic bags, bottles, sheet/sacks), household - technical plastics, and construction plastics. The energy benchmarking is established based on specific energy consumption (SEC) in the process. The study results reveal the difference both in SEC levels and the ranges of SEC of various sub-sectors. The outcome of the research shows that the plastic bottle has the widest range of SEC between 0.18 and 3.35 kWh/kg. In contrast, the narrowest variation of SEC is in the construction and plastic bag. Two these sub-sectors also have a lower medium of energy efficiency index, at 0.48 and 0.49 kWh/kg, respectively. From the energy benchmarking results and the sub-sectors scale, the estimated energy-saving potential of the plastic bag is fingered out as the highest energy potential group at 148 million kWh.

Keywords: energy benchmarking, specific energy consumption, plastics industry.

1. Introduction

In today's competitive market, entrepreneurs are aware of the need to reduce production costs to compete with other competitors and increase profits. Reducing energy costs is as one of the effective measures to get those targets. Energy benchmarking is about the setting targets to save money on energy and improve energy performance which drives cost reduction [1]. There are three basis energy benchmarking methods as follows:

- Benchmarking based on model simulation;
- A rating system based on grades;
- Benchmarking according to statistical analysis method.

Energy consumption is affected by many factors including production facility, manufacturing procedure, factory layout, worker behaviors, weather conditions, etc. In order to investigate the influence of these factors on the energy consumption, model simulation is preferred [2]. These models have the advantage of being able to estimate many parameters that affect energy efficiency, but this method requires very large data sets and complex simulation models. Large data sets are normally not available and defining mathematical shapes of simulation models is a tough task [3].

The grading method based on scores consistent with energy consumption benchmarking for buildings [4]. This approach is now widely used in the United States and other countries under the application of Energy Star [5]. In industry, the benchmark rating reflects the relationship between the energy consumption of the process and the expected value [6]. The advantages of this method are the simplicity; however, the evaluation can be not accurate because of relative inputs. Using this method, we also do not see in specific the reasons for low energy efficiency.

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Corresponding author. Tel.: +84 904048884; E-mail address: hiepdtd@epu.edu.vn

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Lastly, it is popular and valuable to analyze the historical data of energy consumption. From that, we can discover the efficiency of energy use as well as build the benchmark range. Determining the benchmark for buildings, some types of statistical analysis method are also employed. Ordinary least of square (OLS) [7], stochastic frontier analysis (SFA) [8], and data envelopment analysis (DEA) [9] are used in many pieces of research. In industry, estimating specific energy consumption (how much energy is consumed per one unit of products) concerning machines, processes, or factories is useful and valuable for defining energy benchmarking.

We realize that each method has certain advantages and disadvantages. Depending on the available of data sets, the complexity of energy users, the enterprise or government objectives, we employ a suitable methodology to define energy benchmarking. However, whatever the method is chosen, in order to set the targets on using energy sources, it is necessary to investigate the current status and future trends for energy use, energy efficiency, technologies. The assessment would, in turn, be used to determine the potential and cost-effectiveness of energy efficiency improvement and develop an energy efficiency action plan for the industry.

Regarding the plastic product manufacturing sector in Vietnam, this industry is a fast developing both in production output, employment but also in its energy usage [10] [11]. There are specific attributes that differentiate the plastic sector in Vietnam from other industries such as the chemical sector. Firstly, the plastic sector predominantly uses electricity as the main energy source, mainly in the form of electrical driven motive power and electrically based cooling and heating systems. Secondly, unlike many other sectors of the processing industry, the plastic processing is not a continuous flow process but has several steps such as conveying, drying, extrusion, molding, cooling. The efficiency of one step may affect the outcome of another. Thirdly, the lack of a natural gas distribution network has restricted the potential for the use of cogeneration system in plastic factories hence and the potential energy and environmental cost savings associated with it. Fourthly, the presence of relatively cheap electricity and the availability of cheap and mostly inefficient plastic processing equipment, particularly from China have encouraged much Vietnamese plastics manufactures to invest in these low-cost options. Fifthly, due to the complicated nature of the science behind plastic processing, the industry often employs process specific experts who have traditionally focused on the plastic processing science with little attention if any paid to the efficiency implications of process design. Sixthly, unlike some other industrial sectors such as the chemical sector, the plastic sector is highly customers demand driver and it is common to find multiple products been manufactured in one factory. Lastly, a product specification is dependent on the customer requirements it can change regularly meaning that the producers need to be very flexible in their choice of processes equipment. The high turn-around of product types results in high level of process equipment set-ups changes in terms of mold changes etc. resulting in high energy standing losses due to idling equipment.

Considering the energy benchmarking method for an industry in general, particularly the characteristics of the plastic sector in Vietnam, we propose to apply the methodology of statistical analysis for discovering the energy-saving potential. Some previous studies reveal the advantages of this method in the plastics industry. With this method, site load and machine load are defined to estimate specific energy consumption [1] [12]. Energy benchmarking for the plastics industry is described through specific energy consumption in processes. It provides valuable information to stakeholders to establish energy efficiency targets more feasible.

Energy efficiency and energy-saving policies are the best way to push enterprises implementing the energy-saving measures. Along with cement, steel, paper, textile, beverage, sugar, chemistry, plastic sector is evaluated to have a high potential of energy saving. In this article, we develop a methodology for determining the energy benchmarking for the plastics industry in Vietnam. The paper is divided into five sections and step by step clear the methodology as well as the results of the research. We investigate the energy consumption in the plastics industry in Vietnam in section 2. In section 3, the methodology for calculating the energy efficiency index for the plastic is developed. Section 4 is to demonstrate the result of specific energy consumption and energy-saving potential for sub-sectors. Finally, some conclusions

and policy implications are given in section 5.

2. Energy Consumption in the Plastics Industry in Vietnam

Plastics industry is one of the significant energy consuming sectors in Vietnam. In 2013, the plastic enterprises consumed about 212,829 TOE, accounting for around 1% of the energy consumed by the entire industry [VNEEP, 2014]. Energy cost accounted for 2 - 10% of the production cost of plastic enterprises. Electricity is the main source of energy for the plastics industry. The electricity is consumed in main production processes such as heating for extruders, manufacturing machines, plastic resin heaters; utility systems such as cooling system, chiller, compressed air system; administration area including air-conditioning, ventilation, lighting, etc. According to the Decision 1535/QD-TTg of the Prime Minister dated 28 August 2014, issuing the list of significant energy consumers in Vietnam, eighty plastic companies were on the list.

Plastic products are variety and diversity. Five main plastic products are identified for energy benchmarking shown in Fig 1.

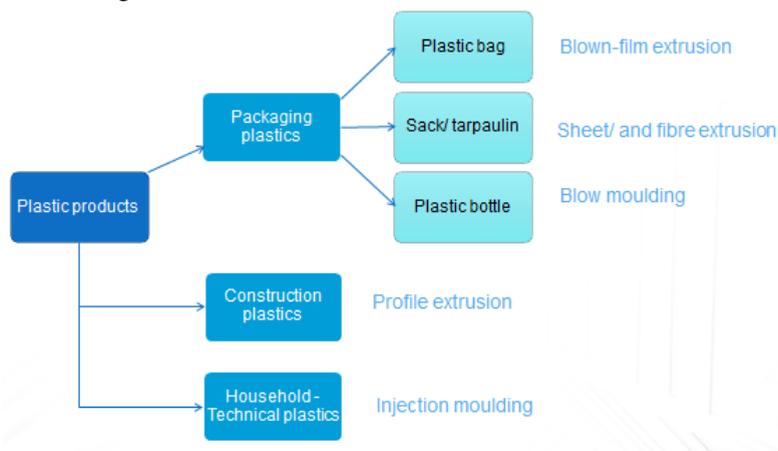


Fig. 1. Plastics product categories

Based on the similarity of manufacturing processes, energy consumption, we divide them into three sub-sectors as below:

- Packaging plastics include plastic bags, bottles, and sheet/sacks. We separate them into three technology groups consisting of plastic bags manufactured through a blown-film extrusion process, plastic sacks, tarpaulin, tape, sheet and clothing manufactured through sheet/fiber extruding process, and plastic bottles manufactured through blow molding process.
- Construction plastics: plastic pipes, plastic doors, plastic frames, plastic roof and wall manufactured through a profile extrusion process.
- Household-technical plastics are the produced products through injection molding process.

The enterprises producing products belonging to more than one of the above groups, namely mix-product enterprises.

The plastics industry in Vietnam had about 1200 enterprises, where the size of enterprises was different, many small manufacturers. Among 706 plastic enterprises considered, 473 enterprises are small-scale one (under 30 employees) (Fig 2). However, the turnover of those enterprises contributed only 6.8% of total industry revenue. Furthermore, this type of enterprises consumes an insignificant amount of energy. The estimated energy consumption of this small-scale enterprise group is accounted for 9.7% of the total energy consumption of the whole plastics industry. In summary, more than 90% of the energy consumption of Vietnamese plastic sector is concentrated in 233 enterprises [GSO, 2015].

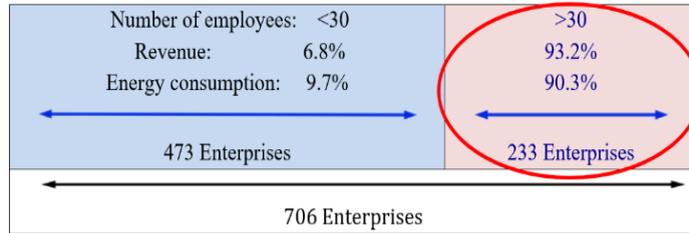


Fig. 2. Characteristic of plastics enterprises in Vietnam

Of the 233 enterprises with a workforce of more than 30 laborers, the share of energy consumption in enterprises by product group is as follows:

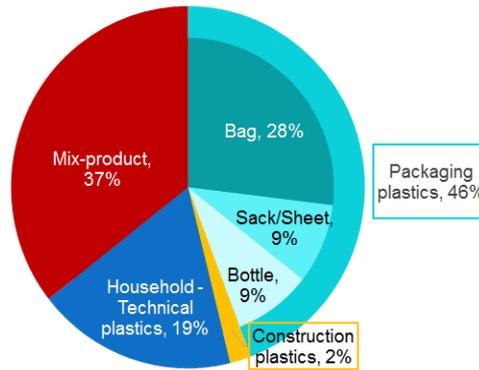


Fig. 3. Share of energy consumption in enterprises by product groups

Energy consumption in packaging enterprises accounted for a sizeable proportion, almost half of the industry's energy consumption. Energy consumption in mixed enterprises (producing more than one type of product) ranked second (37%), followed by energy consumption in household/technical plastic. Energy consumption in construction plastic products enterprises accounted for the lowest proportion (Fig 3).

3. Methodology of Energy Benchmarking

When it comes to the term “energy benchmarking”, we are referring to the comparison of energy consumption at facilities with similar characteristics, such as among plastic factories, steel manufacturers, or office buildings. Energy benchmarking is a useful tool for businesses to manage energy consumption. In some countries, the energy benchmarking is used by governments as a political tool to set energy policies. To quantify the energy consumption, one of the crucial factors which are necessary to determine to be energy efficiency index. Comparing the energy efficiency index with the same enterprise or with the best unit is a method to establish benchmarking. For industries, the most common energy efficiency index is the energy consumption per unit of product.

The principle of the method is based on energy efficiency index of selected enterprises to rank enterprises into the group: 25% of enterprises into the best group, 25% of enterprises into the good group, 25% enterprises are on average, and 25% of businesses are poor. Comparing the differences in the energy efficiency indexes of the groups against the best ones will estimate the potential energy savings of the sector.

To establish the energy benchmarking based on the process, we implement through the following steps:

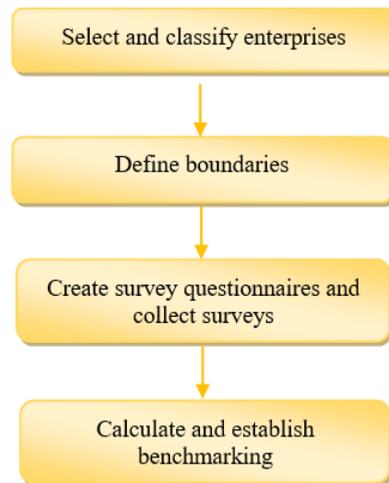


Fig. 4. Steps of energy benchmarking determination

3.1. Enterprise selection and classification

The selection of surveyed enterprises to obtain data on the construction of energy benchmarking according to the process is determined based on the following criteria:

- Selected enterprises are companies that produce plastic products only.
- The selected enterprises are diversity in size.
- It is a priority to select companies with meter systems to monitor energy consumption and output.

According to the measurement system at the factory, we classify enterprises into three categories:

Type 1 factories: These are industries that produce one or more products and have metering systems that record energy usage and production rates for all products produced. Also, they have information to allow non-production energy usage and utility energy usage and non-production usage can be identified either by metering or by analysis.

Type 2 factories: These industries produce only one plastic product. They have no sub-metering, except the main electricity meter and any thermal energy usage. They measure the amounts product produced and have information on the energy usage by the utility systems (or this energy usage can be measured on site).

Type 3 factories: These industries may produce one or more plastic products. They have no sub-metering, except the main electricity meter and thermal metering if any. They measure the amounts of all products produced.

3.2. Boundary definition

Electricity is the main source of energy used by plastics processors. Therefore, in this research, the energy consumption is calculated based on the electrical energy. Applying benchmarking boundaries will ensure that the benchmarking data relating to each factory represent similar processes and systems. To achieve this objective, the areas chosen for assessment need to be ring-fenced. The energy usage in the non-production areas is excluded from the analysis in the case of process related specific energy usage which is the basis of the Vietnamese benchmarking process.

After examining the plastic products, we propose the following scope of research:

- Calculation of energy benchmarking for three sub-sectors: plastic packaging (plastic bags, plastic bottles, plastic sacks/sheet), household/technical plastics, and construction plastics.
- To calculate the SEC for each product, it is necessary to collect data on energy consumption and output in the production area (production machinery and utility equipment).

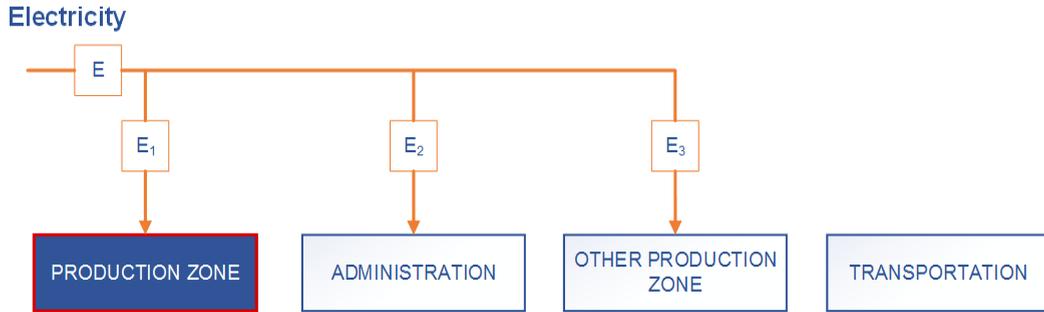


Fig. 5. Boundary of the energy benchmarking exercise

The equipment included in the energy consumption based on process includes: (1) machines and equipment in the main production area; (2) utility equipment (air compressor, cooling tower, chiller); (3) plastic grain drying equipment; (4) recycling facilities (generator, cutter, etc.).

The excluded equipment in the process energy consumption consists of areas within the plastic factory but no activities related to the plastic manufacturing process. Also, energy consumption in the office area, a dining room is out of the calculation. Besides, energy consumption in warehouse areas, distribution centers, and other transport equipment is also ignored.

3.3. Calculation of specific energy consumption

For type 1 factories, since sub-metering of electricity is available for all product types as well production output. For type 2 factories, there are no electricity sub-meters, but the main utility meter information allows for the annual electricity usage to be determined. The SEC of the process for each product type 1 or 2 can be calculated as described in the above equations:

$$SECp = \frac{E - (E_2 + E_3)}{A} = \frac{E_1}{A} = \frac{PEC * E}{A} \quad (1)$$

- $SECp$: Process specific energy consumption (kWh/kg).
- E : Total of electricity usage of a factory per year (kWh).
- E_2, E_3 : Total of electricity usage in administration area and non-production area (kWh).
- E_1 : Total of electricity consumption in production area (kWh).
- PEC : Share of energy consumption in production area (%).

For type 3 factories: with annual production and consumption data for the factories type 3, the SEC is calculated from factories type 1 and type 2, we define the relative SEC for factories type 3. This method is a temporary solution until these plants install energy meter systems for each type of product. However, because factories type 3 produce various products, it is not possible to compare specific energy consumptions. Therefore, in the scale of this work, we only focus on determining energy benchmarking for factories type 1 and 2.

4. Energy Benchmarking for the Plastics Industry in Vietnam

4.1. Sample

After conducting an energy audit for 21 plastic enterprises, we sent general survey questionnaires to 200 remaining enterprises, and 92 responses were received. The full set of data (including production output and energy consumption for each main product) was obtained for the total of 81 enterprises, accounting for 55.86% of 145 the plastic enterprises (excluding the mix-product enterprises). The market share of these 81 enterprises was 52.46% of the whole sector excluding the mix-product enterprises, as shown in Table 1.

Table 1. Overview of plastics sectors

Category	Packaging plastics			Construction	Household/T echnical	Total
	Bag	Bottle	Sack/ Sheet			
Initial Assessment						
Number of enterprises	94	18	52	12	21	145
Production 2013 (ton)	593,196	65,700	240,382	178,676	172,280	1,250,233
Energy audit and survey						
Number of enterprises	36	11	10	8	16	81
Share of enterprises (%)	38.30	61.11	19.23	66.67	76.19	55.86
Production 2013 (ton)	265,626	25,179	90,900	124,626	137,053	643,384
Share of Production (%)	44.78	38.90	38.65	69.75	79.55	51.46
Electricity consumption (MWh)	131,228	54,619	43,186	60,104	142,096	431,233

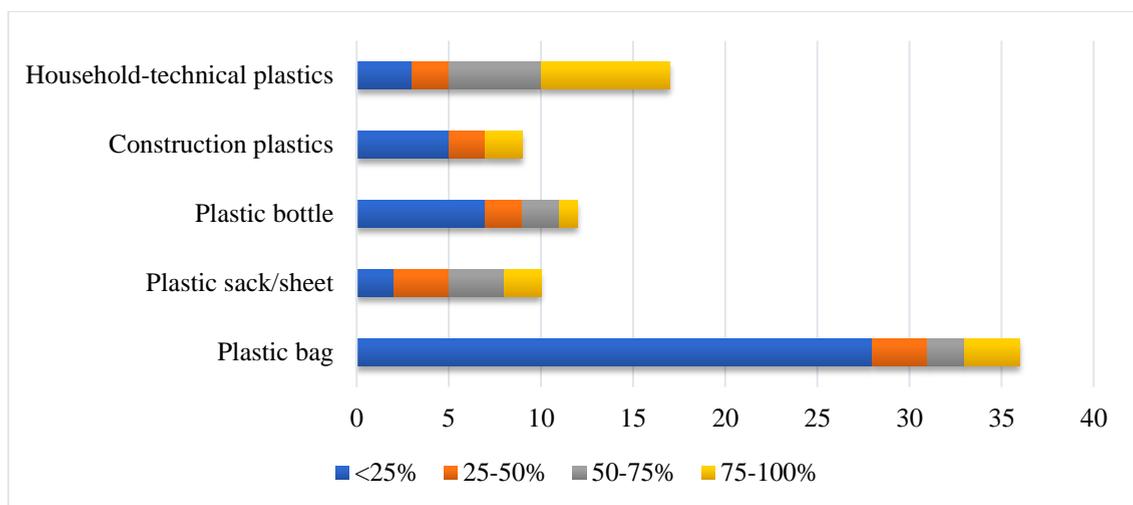


Fig. 6. Proportion of sample by the output range

All large and small production capacity enterprises were included in the energy audit and survey as shown in Fig 6. Each product category was divided into 4 range of output: <25%, 25-50%, 50-75% and 75-100%. The output of the largest enterprise in each sector was considered as 100% output.

Therefore, it could be considered that the sampling enterprises were representative of the Vietnamese plastic sector in term of market share and output range.

4.2. Boundaries of energy benchmarking

4.2.1. Plastic bag

For plastic bag producers, the production zone consists of two areas: (1) machinery area includes raw material handling and mix/heating, blown-film extrusion, film winder and slitting/cutting and grinders

machines, (2) utility area includes cooling tower/chiller and air compressor systems.

The energy consumption for cutting/slitting apart might be different due to the size requirement of the products. The other parts in the machinery area (including mix, heating, film blowing, and winder parts) are required in all plastic bag factories. Therefore, in machinery area, all these parts will be normalized for the general process, namely Blown-film Extrusion area with energy consumption proportion of extrusion (75.5%), utility (19.4%), and office (5.1%).

4.2.2. Plastic bottle

For plastic bottle producers, the production zone consists of two areas: (1) machinery area includes raw material handling and mix/heating, blow molding, burr cutting and grinder machines, (2) utility area includes cooling tower/chiller and air compressor systems. There are two types of blow molding process: extrusion blow molding process, injection blow molding process with a separated process or continuous process.

Therefore, the normalized energy consumption proportion for a plastic bottle is separated in two sets. If the input material is plastic resin, blow molding (including injection molding or extrusion part) (72.1%), utility (18.0%) and office (9.9%). If the input material is plastic mold: Blow Molding (69.2%, in which 35.2% is accounted for the dummy energy consumption for Injection Molding process to produce plastic mold), utility (27.4%) and office (3.3%). In another word, if the total energy consumption of the plastic bottle producer using plastic mold as the input material is X, the dummy energy consumption which needs to be added up is equal to 50.5% of X.

4.2.3. Plastic sacks/sheet

For plastic sack/sheet producers, the production zone consists of two areas: (1) machinery area includes raw material handling and mix/heating, fiber/sheet extrusion, fiber/sheet winder and grinder machines, (2) utility area includes cooling tower/chiller and air compressor systems.

The energy consumption for grinder and cutting/slitting part might be different due to the size requirement of the products and the operation procedure of the factory. The other parts in machinery area (including mix, heating, fiber/sheet extrusion, winder parts) are required in all plastic sack/sheet factories. Therefore, in machinery area, all those parts will be normalized for the general process, namely fiber/sheet extrusion area with the energy consumption proportion of Sheet/Fiber extrusion (74.6%), utility (20.6%) and office (4.8%).

4.2.4. Construction plastic

For construction plastics, the production zone consists of two areas: (1) machinery area includes raw material handling and mix/heating, profile extrusion, cooling bath, cutting and grinder machines, (2) utility area includes cooling tower/chiller and air compressor systems.

The energy consumption for the grinder part might be different due to the operation procedure of the factory. The other parts in the machinery area (including mix, heating, profile extrusion, cooling bath, and cutting) are required in all construction plastics factories. Therefore, in Machinery area, all these parts will be normalized for the general process, namely Profile Extrusion area with the energy consumption proportion of profile extrusion (83.5%), utility (15.1%) and office (1.4%).

4.2.5. Household-technical plastic

For household/technical plastics, the production area consists of two areas: (1) machinery area includes raw material handling and mix/heating, injection molding, burr cutting and grinder machines, (2) utility area includes cooling tower/chiller and air compressor systems.

The energy consumption for the grinder part might be different due to the operation procedure of the factory. The other parts in the machinery area (including mix, heating, injection, molding and burr cutting) are required in all construction plastics factories. Therefore, in machinery area, all these parts will be normalized for the general process, namely Injection Molding area with the energy consumption

proportion of (84.2%), utility (10.9%) and office (4.9%).

4.3. Energy benchmarking and energy-saving potentials

4.3.1. Plastic bag

The process SEC varies from 0.16 to 2.13 kWh/kg, the median process SEC for participating plastic bag enterprises is 0.49 kWh/kg (Fig. 7).

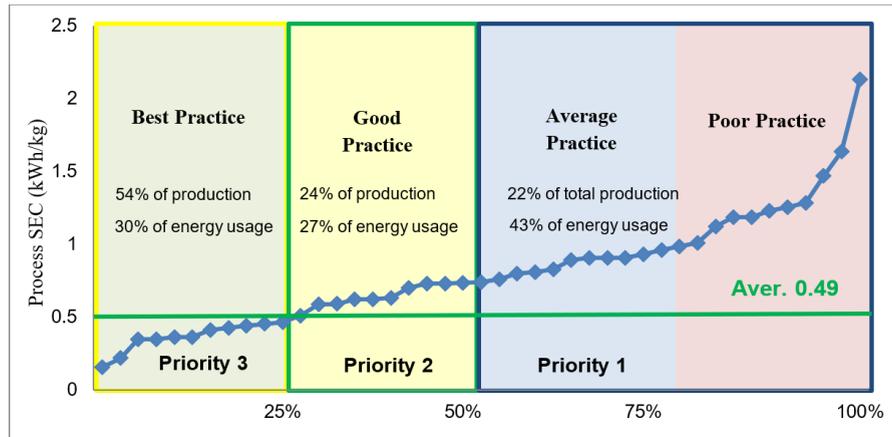


Fig. 7. Energy benchmarking of sampled plastic bag enterprises

From energy benchmarking results, energy-saving potentials, from 19-51%, are calculated by determining the deviation between the actual process SEC for each factory in each group and the median process SEC of the Best practice group as shown in Table 2. Taking energy savings divided the total energy consumption of all plastic bag enterprises, we get potential energy saving in percentage.

Table 2. Energy-saving potentials of sampled plastic bag enterprises

Practice	Electricity (MWh)	Output (ton)	SEC range (kWh/kg)	Mean SEC (kWh/kg)	Savings (MWh)	Saving potentials (%)
Best	39,297	143,325	0.16-0.44	0.27		
Good	35,055	64,081	0.44-0.70	0.55	25,444	19.39%
Average	36,174	41,100	0.70-0.99	0.88	26,256	20.01%
Poor	20,702	17,170	0.99-2.13	1.21	15,026	11.45%
Total	131,228	265,676		0.49	66,725	50.85%

The benchmarking energy-saving potential as derived is a total of 50.85%, contributed by 19.39% for the good, 20.01% for the average, and 11.45% for the poor. The estimated total energy consumption of the plastic bag category is 293 million kWh based on the total output of 36 enterprises divided the total output of sub-sectors. And the estimated energy potential of the sector is 148 million kWh is calculated by energy savings multiplied this proportion of output.

4.3.2. Plastic bottle

The calculated process specific energy consumption of plastic bottles varies from 0.18 to 3.35 kWh/kg, the median process SEC for participating plastic bottle enterprises is 1.52 kWh/kg (Fig 8).

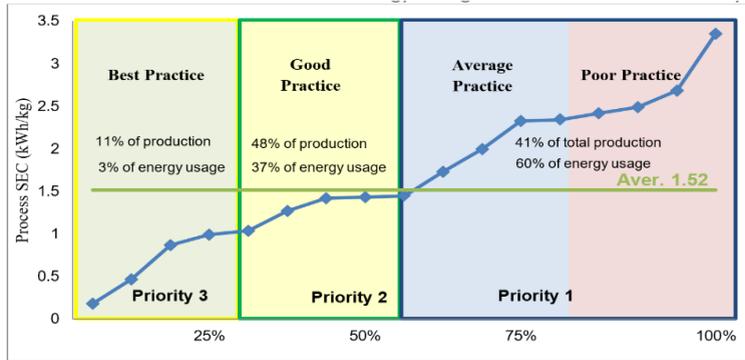


Fig. 8. Energy benchmarking of sampled plastic bottle enterprises

From benchmarking results, energy-saving potentials, from 11% to 50%, were calculated by determine the difference between the actual process SEC for each factory in each group and the median process SEC of the Best practice group as shown in Table 3.

Table 3. Energy-saving potentials of sampled plastic bottle enterprises

Practice	Electricity (MWh)	Output (ton)	SEC range (kWh/kg)	Mean SEC (kWh/kg)	Savings (MWh)	Saving potentials (%)
Best	1,369	3,963	0.18-0.99	0.35		
Good	20,506	17,248	0.99-1.45	1.19	6,494	11.89%
Average	14,286	7,273	1.45-2.35	1.96	8,378	15.34%
Poor	18,457	7,395	2.35-3.35	2.50	12,450	22.79%
Total	54,619	35,879		1.52	27,321	50.02%

The benchmarking energy-saving potential as derived is a total of 50.02%, contributed by 11.89% for the good, 15.34% for the average, and 22.79% for the poor. The estimated total energy consumption of the plastic bottle category is 139 million kWh; the estimated energy potential of the sector is 69 million kWh.

4.3.3. Plastic sacks/sheet

The calculated process specific energy consumption of plastic sack/sheet is varied from 0.11 to 1.5 kWh/kg, the median process SEC for participating plastic sack/sheet enterprises is 0.66 kWh/kg (Fig 9).

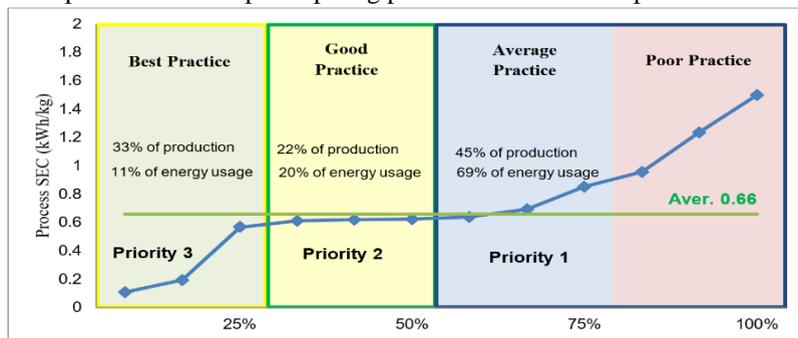


Fig. 9. Energy benchmarking of sampled sack/sheet enterprises

From benchmarking results, energy-saving potentials, from 13% to 68%, were calculated by determine the difference between the actual process SEC for each factory in each group and the median process SEC of the Best practice group as shown in Table 4.

Table 4. Energy-saving potentials of sampled plastic sack/sheet enterprises

Practice	Electricity (MWh)	Output (ton)	SEC range (kWh/kg)	Mean SEC (kWh/kg)	Savings (MWh)	Saving potentials (%)
Best	6,479	31,031	0.11-0.57	0.21		
Good	12,391	20,185	0.57-0.62	0.61	8,176,403	13.38%
Average	16,831	21,427	0.62-0.85	0.79	12,357,241	20.22%
Poor	25,404	20,257	0.85-1.50	1.25	21,174,500	34.65%
Total	61,104	92,900		0.66	41,708	68.26%

The benchmarking energy-saving potential as derived is a total of 68.26%, contributed by 13.38% for the good, 20.22% for the average, and 34.65% for the poor. The estimated total energy consumption of the plastic sack/sheet category is 159 million kWh; the estimated energy potential of the sector is 108 million kWh.

4.3.4. Construction plastics

The calculated process specific energy consumption of construction plastics is varied from 0.22 kWh/kg to 1.29 kWh/kg. The median process SEC for participating construction plastics is 0.48 kWh/kg (Fig 10).

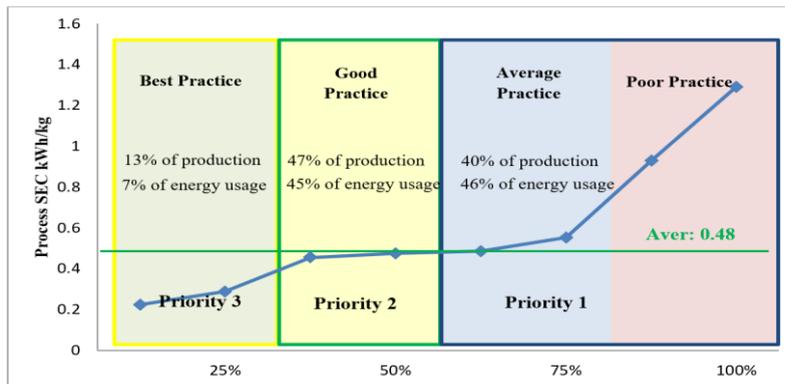


Fig. 10. Energy benchmarking of sampled construction plastic enterprises

From benchmarking results, energy-saving potentials, from 17.19% - 41.58%, were calculated by determine the difference between the actual process SEC for each factory in each group and the median process SEC of the Best practice group as shown in Table 5.

Table 5. Energy-saving potentials of sampled construction plastic enterprises

Practice	Electricity (MWh)	Output (ton)	SEC range (kWh/kg)	Mean SEC (kWh/kg)	Savings (MWh)	Saving potentials (%)
Best	4,431	15,728	0.223-0.288	0.282		
Good	26,752	58,272	0.288-0.475	0.459	10,333	17.19%
Average	21,124	42,555	0.475-0.553	0.496	9,133	15.20%
Poor	7,796	8,071	0.553-1.290	0.966	5,522	9.19%
Total	60,104	124,626		0.482	24,989	41.58%

The benchmarking energy-saving potential as derived is a total of 41.58%, contributed by 17.19% for the good, 15.20% for the average, and 9.19% for the poor. The estimated total energy consumption of the construction sector is 86 million kWh, the estimated energy-saving potential of the sector is 36 million kWh.

4.3.5. Household/technical plastics

The calculated process specific energy consumption of household-technical plastics is varied from 0.42 kWh/kg to 1.76 kWh/kg. The median process SEC for participating household-technical plastics is 1.04 kWh/kg (Fig 11).

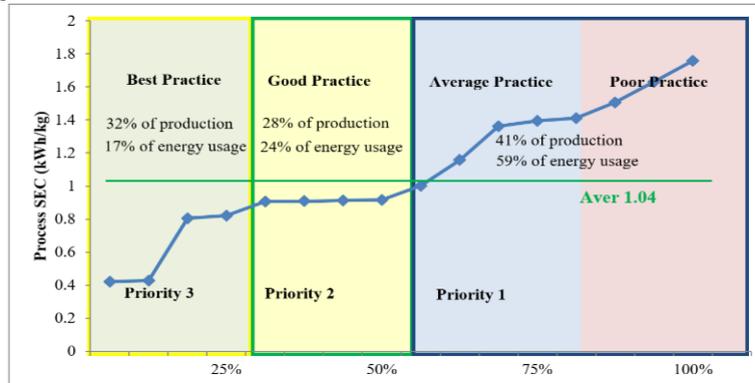


Fig. 11. Energy benchmarking of sampled household/technical plastic enterprises

From benchmarking results, energy-saving potentials, from 9.11% to 44.78% were calculated by determine the difference between the actual process SEC for each factory in each group and the median process SEC of the Best practice group as shown in Table 6.

Table 6. Energy-saving potentials of sampled household/technical plastic enterprises

Practice	Electricity (MWh)	Output (ton)	SEC range (kWh/kg)	Mean SEC (kWh/kg)	Savings (MWh)	Saving potentials (%)
Best	24,751	43,234	0.422-0.822	0.572		
Good	34,788	38,148	0.822-0.916	0.912	12,948	9.11%
Average	22,033	18,672	20.916-1.394	1.180	11,344	7.98%
Poor	60,523	36,998	1.394-1.759	1.636	39,342	27.69%
Total	142,096	137,053		1.037	63,634	44.78%

The benchmarking energy-saving potential as derived is a total of 44.78%, contributed by 9.11% for the good, 7.98% for the average, and 27.69% for the poor. The estimated total energy consumption of the Technical/Household plastic sector is 178 million kWh; the estimated energy potential of the sector is 80 million kWh.

5. Conclusions and Policy Implications

The main contribution of this study is that we propose the valuable approach for determining energy benchmarking for sub – sectors of the plastics industry in Vietnam. With the proposed methodology, we find out the difference both in SEC processes of various sub-sectors and the range of SEC. The results show that the plastic bottle has the widest range of SEC between 0.18 and 3.35 kWh/kg. In contrast, the narrowest variation of SEC is in the construction and plastic bag. Two these sub-sectors also have a lower

medium of energy efficiency index, at 0.48 and 0.49 kWh/kg, respectively. Table 7 summarizes the range and medium of SEC of plastic sub-sectors

Table 7. Range and medians of SEC of plastic groups

Sub - sectors	Range of SEC (kWh/kg)	Median of SEC (kWh/kg)
Plastic bag	0.16 – 2.13	0.49
Plastic bottle	0.18 – 3.35	1.52
Plastic sack/sheet	0.11 – 1.5	0.66
Construction plastics	0.22 – 1.29	0.48
Household – technical plastics	0.42 – 1.76	1.04

From the energy benchmarking results and the industry scale, the estimated energy potentials of the sub-sectors are 148, 69, 108, 36 and 80 million kWh for plastic bag, plastic bottle, plastic sack/sheet, construction plastics, and household – technical plastics, respectively. Thus, each enterprise in the plastics industry can compare the specific energy consumption of the company with the index of sub-sector and realize the saving energy potential. The energy benchmarking motivates for enterprise to take appropriate action to reduce energy consumption as well as energy costs in their units. The estimated specific energy consumption can be used as input for constructing policies of energy efficiency and energy saving.

From this study, we propose some policies to overcome a number of barriers to energy efficiency implementation in the plastics industry. First of all, because of the lack of energy sub-metering in the plastic sector, the proposed government circular should have advised industry to install the necessary metering systems to enable the calculation of their benchmark value. Secondly, for new build factories and extensions to existing factories or expansions to existing factories, regulations and guidelines are required to ensure that new build factories and extensions conform to minimum efficiency standards. Thirdly, the government should introduce legislation that will require a focus on energy efficiency as a condition of the granting of an integrated pollution control license. Fourthly, for Vietnamese industries in general, particularly the plastics industry, because it is difficult to access finance in the banking system for energy-saving projects, the government should also consider how banking institutions can offer special incentive loans for energy efficiency improvements. Government loan guarantees is another option. Last but not least, the government should have a steering committee that includes representation of the main stakeholders of the energy-saving action plan to implement the government plan for energy savings in the plastic sector. The responsibility of the authority includes: (1) recommend to the government the benchmarking for industrial processes and energy consumption standards; (2) prescribe guidelines for energy efficiency in new factories or extensions to existing factories; (3) take all measures necessary to create awareness and disseminate information for efficient use in the plastic sector; (4) arrange and organize training of personnel and specialists in the techniques for efficient use of energy and its conversation; (5) give technical assistance to industrial institutions for promoting energy efficiency in the plastic sector; and (6) formulate and facilitate implementation of pilot energy-saving projects and demonstration projects results for promotion of efficient in the plastic sector.

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