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Research article

Energy benchmark and energy saving potential in the pulp and paper industry

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Abstract: In this research, I established an energy benchmark for the pulp and paper industry of Vietnam. I, therefore, focus on three major paper product families, including packaging paper, printing and writing paper, and tissue paper. In this research, I use specific energy consumption (SEC) as the energy performance indicator (EnPI) for computing energy benchmarks for the main sub-sectors in the pulp and paper industry of Vietnam. The factories in the pulp and paper industry of Vietnam are divided into three production scales, and the energy benchmarks are specified by production scales. Energy surveys and energy audits have been used to calculate energy benchmarks. Here, I establish the energy benchmark for the main sub-sectors in the pulp and paper industry of Vietnam according to the three production scales. I also estimate the energy saving potential for the pulp and paper industry of Vietnam based on surveying and auditing results.

Keywords: energy benchmark; energy saving potential; specific energy consumption; pulp and paper; energy audit

1. Introduction

Green growth is an important trend in the world economy. The green growth strategy is approved as an important development strategy of Vietnam [1]. To deploy this green growth strategy, a series of national goal programs have been implemented and have achieved good results. The Vietnam National Energy Efficiency Program (VNEEP) is among the important national goal programs of Vietnam that have been implemented through several stages and have obtained satisfactory achievements. The

VNEEP program aims to reduce energy consumption in different areas in which industry is a focused area. Energy efficiency has been proven to be useful to reduce environmental effects and increase economic value [2]. Moreover, the energy efficiency program was very effective in practice [3].

In industry, the VNEEP program concentrated on the reduction of energy consumption through energy audits and motivating energy saving solutions. The program also aims to deploy advanced energy efficiency technologies and implement energy management systems in industrial factories. Heading to the energy consumption reduction goal in industries, proposing a methodology to benchmark for different areas of industries is very important.

The pulp and paper industry plays an important role in Vietnam. This industry was responsible for a large amount of total energy consumption [4,5]. Enterprises in this industry in Vietnam vary from large-scale industrial factories to small-scale local pulp and paper plants characterized by different energy efficiency levels. To benchmark energy consumption in the pulp and paper industry, I need to evaluate the energy key performance indicators in the industry and establish a methodology to deploy benchmarking exercises in the industry. Determining the energy benchmark for industries is an important task in the Vietnam national energy efficiency program [6]. Benchmarking values help enterprises know their level of energy efficiencies in comparison with other companies in the sector according to the general level and scales.

In this research, I focused on benchmarking energy consumption and estimating the energy saving potential of the pulp and paper industry of Vietnam. I relied on the survey data of the pulp and paper industry of Vietnam during 2015–2016 [7]. This data was used to prepare a circular [8] on energy benchmark in the pulp and paper of Vietnam and this circular is in effect at this time. In this paper, I synthesized methods of calculating energy benchmarks and estimating energy saving potentials in the pulp and paper industry of Vietnam. This methodology can be used for future periods and other industries as well. These results were used to support the policymakers to propose energy efficiency policies for the pulp and paper industry of Vietnam.

2. Literature review

Evaluation of energy benchmarking and energy efficiency potential has received much attention from scholars in different industrial areas [9–14]. Studies, in general, have focused on energy efficiency in several areas such as in buildings [11,13], in industries [10,14–17] and in small- and medium-sized enterprises [9,12,18].

Research on enhancing energy efficiency in industries has been carried out in different directions. Several industries have more attention from scholars including the pulp and paper industry [19–22]. Scholars who studied energy efficiency in industries frequently focused on calculating specific energy consumption (SEC) for production stages of technological processes, and then determining the best practice in the field to estimate the energy saving potential [19,20,23,24].

The estimation of the energy efficiency of the whole factory can be implemented through key performance indicators (KPIs) of energy in factories [18]. Energy KPIs (or Energy Performance Indicators of EnPIs) can be chosen according to the characteristics of (stages of) production processes. Several energy efficiency indicators have been proposed in many studies in the literature [19,25]. Towslee [25] indicated that EnPIs can be calculated simply based on input energy and output production. The EnPI can be a simple indicator to monitor a parameter of a specific process, but it can be a composite index influenced by several input parameters.

Andersson and Thollander [19] proposed a model to determine and adjust KPIs in the management process. This research also showed that physical indicators are more frequently used in pulp and paper factories, and economic indicators are frequently used at an overall level. Departmental indicators have been used more frequently than process indicators [18]. Each factory maintained a set of important EnPIs, in which EnPIs were informed with different frequencies to different subjects (top management, process operators, etc.) aiming to meet the monitoring and managing demand of each subject.

Andersson, Arfwidsson [18] focused on the evaluation of the energy efficiency of SMEs by utilizing energy efficiency indicators (EEI). EEI can be used for a system in which KPIs on the energy of the composition processes are synthesized using weights representing constituent processes [26].

EEIs play an important role in efficiently monitoring and managing energy consumption in industrial facilities. These indicators can be used internally or externally to make comparisons with other companies in the same industrial sector. The EEIs can be applied for individual processes or the whole facility. Using these indices is a foundation to evaluate the energy performance of industrial factories. EEI is normally computed as the rate of a KPI of a process with the KPI of the best practice process or can be calculated as the average value of KPIs of the surveyed facility. KPIs, as discussed before, can be specific energy consumption (SEC), energy intensity, or other appropriate indices. SEC is normally used at a lower level of aggregation such as at sector level or product level [20].

Laurijssen, Faaij [20] calculated SEC (a typical type of EnPI) of processes within different paper mills to identify energy improvement potentials at the process level. The SEC value is based on the ratio of total process energy and total production output of the corresponding process during a specific period. While Saygin, Worrell [27] proposed a method to compute EEIs in which these indices were "established based on the relationship of the sector's actual total final energy use (TFEU) according to the international energy statistics and its total best practice energy use (TBPEU) if all its processes were to operate at the level of the international benchmark". In this research, authors also estimated the energy saving potentials of several areas implementing energy benchmark curves. In another study, Hasanbeigi, Hasanabadi [28] used energy intensity to calculate and compare against other plants within the same sub-sector of the textile industry. This research showed that the single energy indicator can be applied for efficiency evaluation in industries generally. In a recent research, Shabbir, Mirzaeian [24] calculated the SEC indicators for the paper industry in Pakistan and benchmarked them against the best available corresponding SEC values in the paper industry of Canada and the United Kingdom.

The establishment of energy indices and energy benchmarks for different industrial areas is one of the important content of the VNEEP program. This program aimed to derive the target SECs for main product families or processes in several industries in Vietnam. This program focused on the establishment of simple EnPIs (such as SEC) for typical products/processes in the industry. Another important task is to set target EnPIs that enterprises in industrial sectors have to reach for their products/processes. These benchmark values need to be appropriate in different perspectives as achievable, motivating and can help to eliminate inefficient products/processes step by step.

From a practical point of view, it is crucial to be able to set up appropriate (energy) SEC values for the pulp and paper industry. If the targets SECs were too high then these would frustrate the paper companies to strive. On the other hand, if the targets were not challenging, then no one would have to try, therefore governments cannot get a desirable level of energy saving expectation. Setting up appropriate (energy) SECs helps to rightly estimate the energy saving potential in practice. In addition, the estimation of the energy saving and conservation potential was a crucial objective of the VNEEP program as well. This data helps to establish policies for lifting energy efficiency in industries in Vietnam.

Establishing energy benchmarks has been carried out by several previous studies [18,20,24]. Scholars frequently focused on benchmarking stages in technological processes [20]. Differently, I aim to determine the energy benchmark and energy saving potential of main product families (or sub-sectors) in the pulp and paper industry of Vietnam.

3. Establishing the energy benchmark in the pulp and paper industry of Vietnam

3.1. Overview of the Vietnam pulp & paper industry

3.1.1. Production

The Pulp and Paper Industry (PPI) of Vietnam was established early and was growing at an average rate of 16.25% annually during the period 2005–2010, but its contribution to the gross output of industry is minor, varying from 1.8–2.0% in the last 8 years (2005–2013). As the population has been growing and the economy has been developing, the domestic demand for paper and paper products was increasing annually and was estimated to grow at 13.5% per year during 2011–2015. However, the current capacity of pulp and paper manufacturing has only been able to supply about 56% of the domestic demand for paper products, as in statistical data in 2010 [7].

The paper products of Vietnam's Pulp and Paper Industry are classified into four groups: Printing and writing, packaging, tissue and joss papers (Table 1).

Table 1. Production capacity of paper and number of facilities in 2014.

Product	Production in 2014, tons/year		No of facilities in 2014	
	Capacity	Actual	<10.000 tons/year	>10.000 tons/year
Packaging papers	1,700,000	1,280,000	198	28
Tissue papers	208,000	-	12	05
Printing and writing papers	590,000	277,000	6	12
Joss papers	160,000	-	37	04
Total	2,658,000	-	302	

3.1.2. Energy consumption

Electricity consumption: Energy consumption in Vietnam paper facilities has varied depending on different technologies, raw materials, product properties, and energy supply. The energy supply consists of two types, electric power and process heat mostly supplied by coal, oil, and gas. However, the consumption of different energy sources in different paper facilities has not been statistically reported. The analysis of the electricity ratios reveals a good level of performance in the Vietnamese pulp and paper industry. The specific electricity consumption of the integrated mills within the survey varies between 2,160 and 6,120 MJ (0.6 and 1.7 MWh) per ADt (air dry tone) of product, with an average of 3,240 MJ (0.9 MWh) per ADt of product. International benchmarks for this category of productions are in the range of 3,600–10,800 MJ per ADt. Here, I assess the specific energy consumption per type of product with consideration of different input materials.

Thermal energy consumption: Approximately 44% of the facilities with annual production below 5,000 ADt have a specific consumption higher than best available technology (BAT) standards, which indicates a good potential for improvement at small-scale facilities. Total energy consumption and cost of the whole pulp and paper industry in 2005 were reported to be 124,813 TOE and 508 billion VND, as detailed in Table 2.

Table 2. Total energy consumption and energy cost of Vietnam PPI in 2005.

No.	Energy	Consumption	Convert to TOE	Cost (Billion VND)
1	Electricity, million kWh	251.30	89,626	233
2	Coal, thousands of tons	199.32	21,606	208
3	DO, million liters	1.64	1,526	12
4	FO, million liters	9.96	9,941	50
5	Gas, tons	72.10	81	1
6	Wood, thousand m^3	15.50	2,029	4
Total			124,813	508

3.2. Determining SEC in the pulp and paper industry

In this research, I studied the energy efficiency in the pulp and paper industry of Vietnam, in which I focused on determining the energy benchmark for three major product families (or three sub-sectors) in the pulp and paper industry of Vietnam. The energy benchmark is established based on the specific energy consumption (SEC) of the paper product families. To do this, I first classified major products in this industry according to standard product specifications in the corresponding area. The calculation of SEC is based on the separation of data for the corresponding product/process and then deciding SEC as the rate between total energy consumption and total production output of the corresponding product in a specific period, for example, one year. With the specific product family, factories need to be classified according to the production sizes to estimate appropriate SECs.

In this case, SEC is used as the energy performance indicator (EnPI) in the pulp and paper industry of Vietnam. SEC of product/process is calculated as the rate of total input energy (electricity and thermal) and the corresponding equivalent total production output. To compute the SEC, products in the pulp and paper industry are classified into several major product families which can use the same method of calculating SEC.

Table 3 shows the three major paper product families (sub-sectors) in Vietnam with some detailed information.

Table 3. Distribution of surveyed factories by sub-sector classification.

Subsector	Number of factories	Total production	No of surveyed factories	Production of surveyed factories, tons/year	% of capacity
Packaging papers	227	1,280,000	20	693,500	54%
Printing and writing papers	13	410,000	7	307,376	75%
Tissue papers	19	176,000	10	107,682	61%

The energy benchmark focused on the production area of facilities. The benchmarking area is the area of production (production line, utility and waste facilities). The energy performance of a manufacturer is identified by energy consumption and its production in the benchmarking areas only (Figure 1).

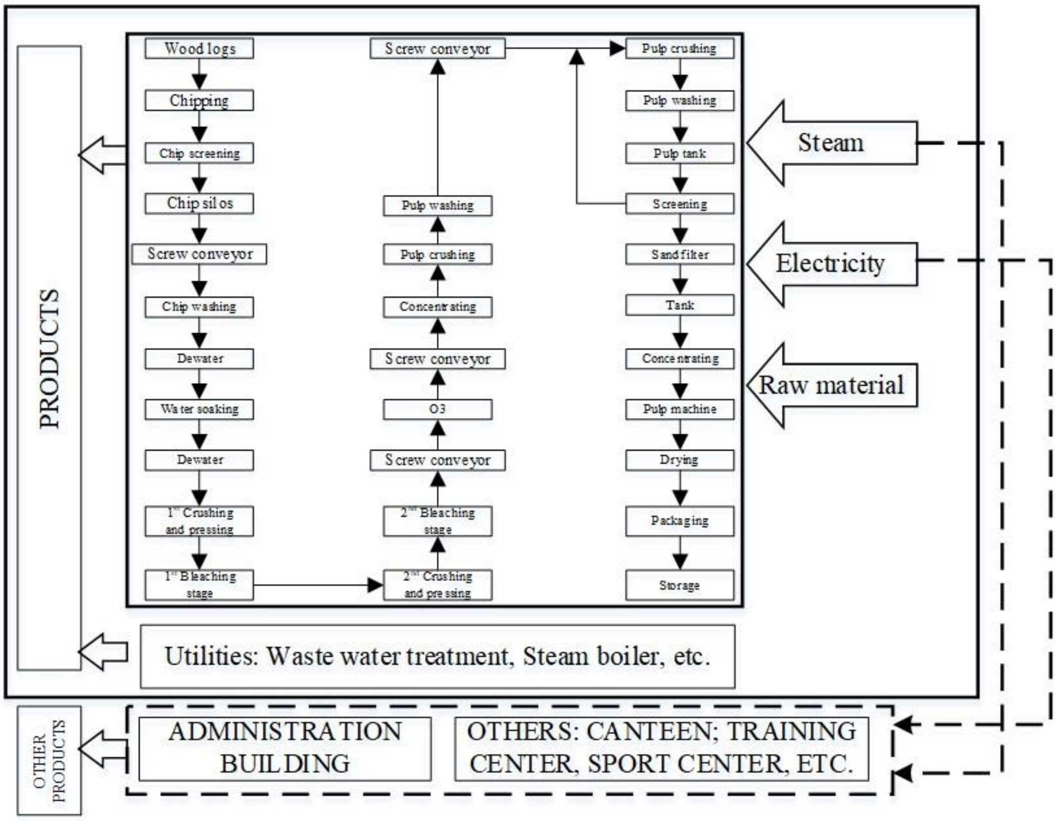

Figure 1. Benchmarking boundaries for semi-chemical processes in the Vietnam pulp and paper industry.

Energy consumption of papermaking processes may vary by different pulps and different products and requires normalization. The energy consumption of paper-making processes consists of electricity for pulp refinement and other machinery, and steam for drying sections. Electricity consumption may vary depending on pulp properties as the pulp treatment processes of different types of pulp are similar. The variation due to different pulp properties could be normalized by converting it into one main pulp. According to the thermal energy calculating equation, steam consumption in the drying section depends on the process parameters such as temperature, weight and humidity of materials, equipment and process control in the form of quantity rather than pulp types or product types.

Based on the international experience in benchmarking exercises for the pulp and paper industry, and for other industries in the world, doing the energy benchmark that takes into account the quality of pulp and paper is quite limited [7]. Laurijssen, Faaij [20] and Shabbir, Mirzaeian [24] mentioned quality of raw materials and paper products in their studies, however, they did not tackle the quality issue in their research. It is very difficult to benchmark according to quality as well because there are lack of existing experiences.

Taking into account all of these factors, it was finalized to carry out benchmarking per range of production scale for each sub-sector (i.e. packaging, tissue, writing and printing sub-sector). Within the scope of this study, the group of production was defined as shown below:

The sector survey was carried out with a target of 136 pulp and paper enterprises among 308 pulp and paper enterprises in the whole industry. Those 136 enterprises produce 1,930,042 tons per year, equivalent to 95% of production capacity.

3.3. Establishing energy benchmark in the pulp and paper industry of Vietnam

3.3.1. Benchmarking methodology

Table describes the process of establishing energy benchmarks for factories in the pulp and paper industry of Vietnam (only focusing on the three major product families or sub-sectors). To determine the energy benchmark, the ideal case is to collect data from all factories in the industry. However, collecting data from all factories is impossible in general and might not be necessary.

In general, energy consumption in the pulp and paper industry is proportional to the production capacity as in industry [29], not the quantities of the factories in the whole sector, as the share of the capacity of the surveyed factories should be more important. According to international experience [7], the total capacity of production of selected sites needs to exceed at least 35% of the whole sector production capacity and the sample factories need to represent factories in different categories [30].

The total capacity of the surveyed factories is 47% (for packaging papers), 77% (for printing and writing papers) and 96% (for tissue papers) of the respective subsector's capacity and the data collection should meet the target as mentioned above. It should be noted that only in Group 3 (small capacity category) under the packaging sub-sector, the total production capacity of the samples does not reach 35% of the total sub-sector capacity as required due to the low interest of the enterprises. However, the collected samples have covered the typical production of this sub-sector to ensure the correct analysis of the energy situation.

The quantity share of the factories in the group of writing and printing paper production and tissue production is above 50%, showing that the surveyed data could represent the subsector's performance. Although the share of surveyed packaging facilities is only 24% in quality, with the number of 28 surveyed factories in the group covering all the scales of production from 1500 tons per year to above 50,000 tons per year, the collected data is enough for the evaluation according to international experience [7].

Table 4. Production scale divisions in the pulp and paper industry.

Group identification	Production range	Scale group
Group 1	<10,000 tons per year	Small scale
Group 2	10,000–50,000 tons per year	Medium scale
Group 3	>50,000 tons per year	Large scale

This research focused on doing energy benchmarks for three sub-sectors of the Vietnam pulp and paper industry (Table 3) and for each sub-sector three scale groups were identified (Table 4). SECs of each product family and scale group were classified by rating (25%) groups (best, good, average, and worst). In a particular situation, the number of rating groups can be different. In general, the average SEC of each scale group was used as the benchmark SEC value for this group. I can also compute the average SEC for the whole specific product family by dividing the total energy used by the total production of the product family.

To estimate the energy saving potential, I can use several approaches. In the first approach, I suppose that all factories with SEC values higher than the average SECs of the whole product family have to reduce their SECs to the average SEC, and then the new average SECs will be calculated again. The distance between old and new average SECs gives us the potential energy saving for this specific group. For the second approach, I do the same way as the previous one for all production scale groups of each product family. In some particular cases, I may do it the same way even for each quartile of production scale groups.

In a later section (3.4), I applied the above first two approaches to estimate energy benchmarks for the three sub-sectors of the pulp and paper industry in Vietnam. The second approach should be an appropriate one since each proposed scale group practically reflects the applications of different technologies for each group. This is particularly true for the printing and writing papers sub-sector.

SEC value for a pulp and paper factory is given below (Eq 1):

$$SEC_{Factory} = \frac{E_e}{P(e)} + \frac{T_e}{P(t)} \quad \text{(MJ/ton)} \tag{1}$$

A factory in a sub-sector (e.g. packaging sector) may produce several paper products; therefore, the SEC value of this factory is calculated using an equivalent product in the corresponding sub-sector. Energy (electricity and thermal) consumption and product quantities are converted into equivalent values for calculation.

- E_e: Equivalent electricity at the production site (MJ),
- T_e: Equivalent thermal energy at the production site (MJ),
- P(e): Equivalent production by electricity consumption (ton),
- P(t): Equivalent production by thermal energy consumption (ton).

Determining E_e, T_e, P(e) and P(t):

a) Equivalent electricity E_e

Equivalent electricity at the production site during the surveyed period converts to MJ as (Eq 2):

$$E_e = E \times 3.6 \quad \text{[MJ]} \tag{2}$$

- E_e: Equivalent electricity at the production site during the surveyed period in MJ,
- E: Equivalent electricity at the production site during the surveyed period in kWh.

b) Equivalent thermal energy T_e

Equivalent thermal energy at the production site during the surveyed period in MJ as (Eq 3):

$$T_e = \sum T_i \times k_i \quad \text{[MJ]} \tag{3}$$

- T_e: Equivalent thermal energy at the production site during the surveyed period in MJ,
- T_i: Amount of fuel consumption at the production site during the surveyed period,
- k_i: Conversion coefficient in Table A2.

c) Equivalent production P(e), P(t) for packaging paper (during surveyed period) (Eqs 4 and 5):

$$P(e) = P_1 + P_2 + 1{,}31 \times P_3 + P_4 \qquad \text{(ton)} \qquad (4)$$

$$P(t) = P_1 + P_2 + 1{,}48 \times P_3 + P_4 \qquad \text{(ton)} \qquad (5)$$

- P(e): Equivalent production by electricity consumption (ton),
- P(t): Equivalent production by thermal energy consumption (ton),
- P_1: Production of testliner,
- P_2: Production of standard medium,
- P_3: Production of sizing medium or coating testliner,
- P_4: Production of chipboard and coreboard or other types in small amounts.

The conversion factor 1.31 and 1.48 for different types of packaging products (testliner, standard medium, coasting testliner, chipboard, and coreboard) are obtained by audit results in RCEE_NIRAS and ENERTEAM [7].

d) Equivalent production P(e), P(t) for tissue paper (during surveyed period) (Eqs 6 and 7):

$$P(e) = P_1 + P_2 + 1{,}33 \times P_3 \qquad \text{(ton)} \qquad (6)$$

$$P(t) = P_1 + P_2 + 1{,}11 \times P_3 \qquad \text{(ton)} \qquad (7)$$

- P(e): Equivalent production by electricity consumption (ton),
- P(t): Equivalent production by thermal energy consumption (ton),
- P_1: Production of tissue paper from Virgin Pulp (VP),
- P_2: Production of tissue paper from recycled paper without DIP (deinked pulp),
- P_3: Production of tissue paper from DIP pulp.

The factors 1.33 and 1.11 are obtained from audits and calculated as in RCEE_NIRAS and ENERTEAM [7].

e) Equivalent production P(e), P(t) for printing and writing paper (during the surveyed period) (Eqs 8 and 9):

$$P(e) = P \qquad \text{(ton)} \qquad (8)$$

$$P(t) = P \qquad \text{(ton)} \qquad (9)$$

- P(e): Equivalent production by electricity consumption (ton),
- P(t): Equivalent production by thermal energy consumption (ton),
- P: Production of printing and writing paper.

3.3.2. Energy consumption benchmarking of packaging plants

Figure 2 represents the energy consumption chart of packaging paper in group 1 (Table 4) according to quartiles with an average value of 6,782 MJ/ton. Average SECs at each quartile were computed according to the average SECs of the products of factories lying within the corresponding quartiles (total energy consumption divided by total production in such a quartile).

The benchmarking study is applied to factories using recycled papers as raw materials to produce packaging papers. The energy consumption represented as specific energy consumption (final SEC) of each factory in the year 2014 is presented in Table 5. The results showed that Group 1 of the subsector, i.e., small factories has lower energy consumption than the larger scale factories, which are usually innovated to improve their production efficiency and product quality. As the product quality has not been compared, the lower SEC of group 1 is explained as the simpler process with fewer stages in the stock preparation section, which has been observed during the preliminary audits at the sample factories.

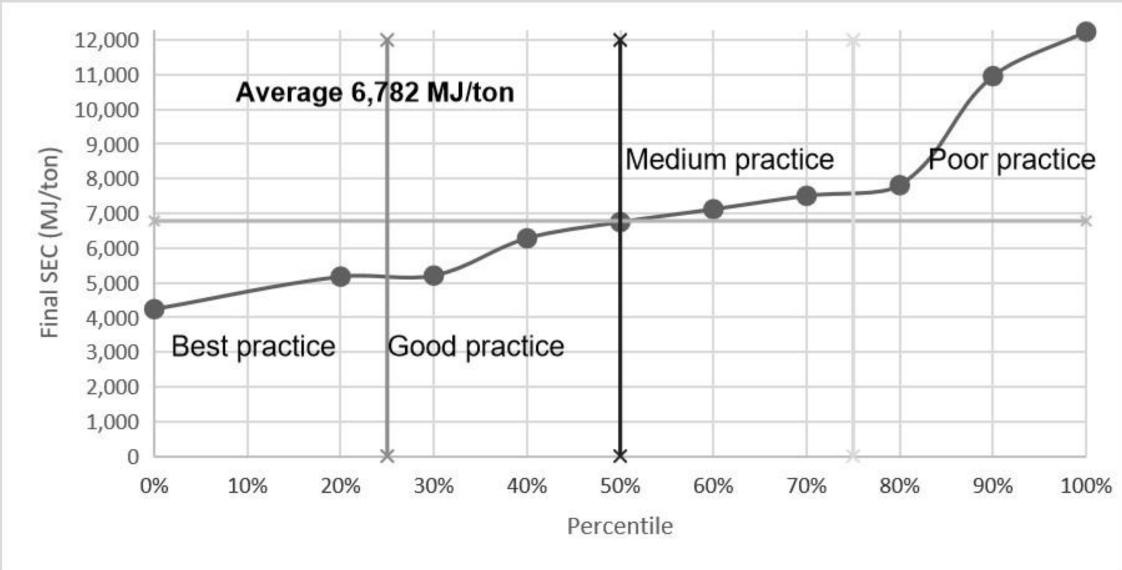

Figure 2. Percentile graph of final specific energy consumption of packaging sector—Group 1 (small scale).

The distribution of final SEC for the packaging sector—group 1 shows the sectorial average final SEC. Figure 2 also indicates that 50% of surveyed factories have the final SEC lower than the sectorial average.

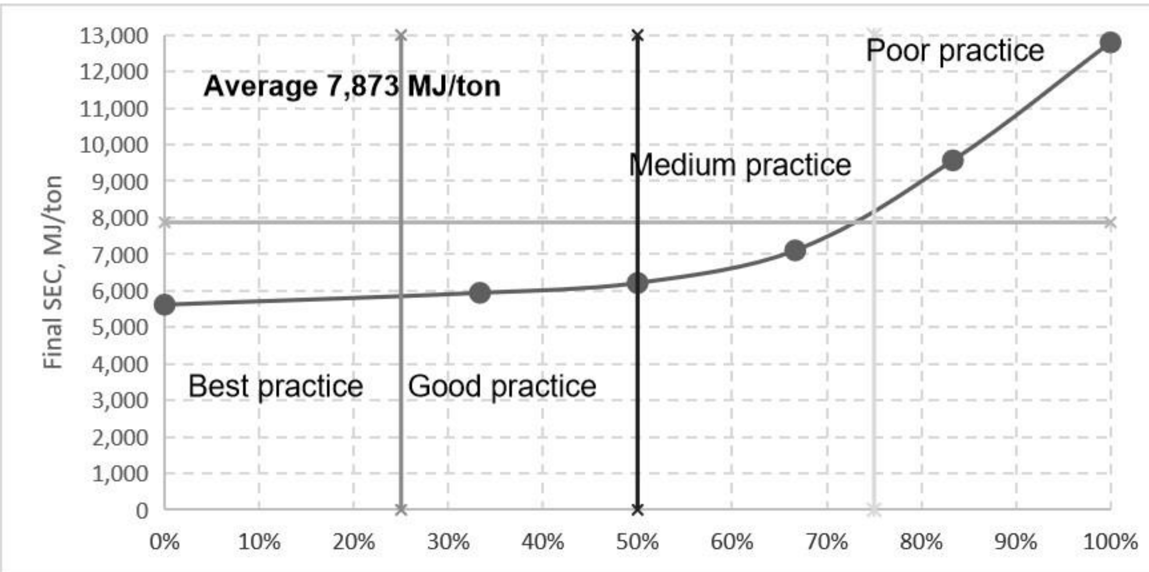

Figure 3. Percentile graph of final specific energy consumption of packaging sector—Group 2 (medium scale).

The distribution of final SEC for the packaging sector—group 2 (Figure 3) shows that the sectorial average final SEC fell in the poor practice area. A total of 73% of surveyed factories have the final SEC lower than the sectorial average. The average SEC of the group 2 and 3 is not different. Factories in group 3 are fully modern production lines or partially upgraded (Figure 4). However, their energy consumption is not lower than that of group 2, which is mostly using old-type machines.

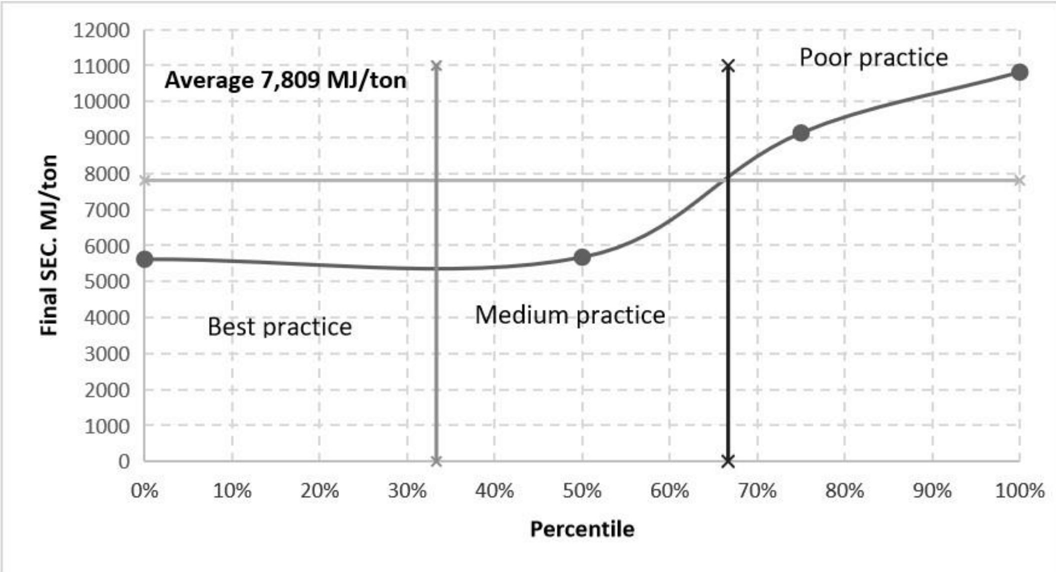

Figure 4. Percentile graph of final specific energy consumption of packaging sector—Group 3 (large scale).

Table 5. Best final SEC and average SEC by groups of factories (packaging paper subsector).

	Average SEC, MJ/ton	Best final SEC MJ/ton
Group 1 (small scale)	6,782	4,237
Group 2 (medium scale)	7,872	5,616
Group 3 (large scale)	7,809	5,617
Whole subsector	7,587	4,237

The best final SEC value and average baseline of group 1 is better than groups 2 and 3 which is due to their simpler production processes, especially in the stock preparation section. This was observed in the preliminary audit at the 20 factories. There is not much difference in the energy consumption of the best practice plants between group 2 and group 3.

3.3.3. Energy consumption benchmarking of tissue paper sub-sector

In Vietnam, tissue papers are produced from two types of fiber sources: Virgin pulp and recycled pulp. The recycled pulp consists of two types- deinked pulp and non-deinked pulp. Deinked pulp processing is found to consume around 10% higher than virgin pulp processing. Most of the medium factories are use the above types of pulp depending on the market demand, and the ratio of raw materials used in the production varies day by day. Therefore, the discrimination in energy consumption of DIP and non-DIP processes among the factories in Vietnam cannot be considered.

The average baseline of small scale tissue paper factories (group 1) is lower in the medium practice, and 68% of the factories have lower SEC values than the average (Figure 5).

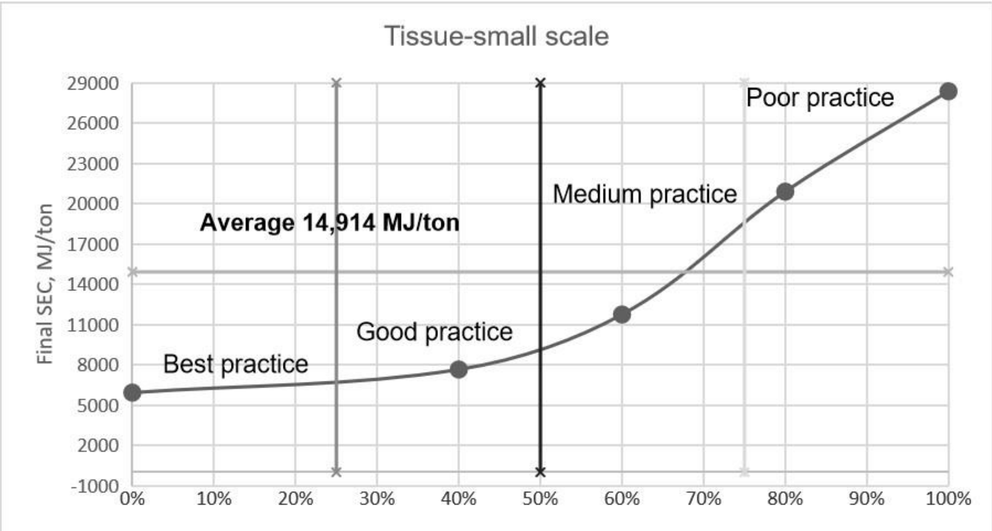

Figure 5. Percentile graph of final specific energy consumption of tissue paper sector—Group 1 (small scale).

The average baseline of medium scale tissue paper factories (group 2) is lower in good practice, and 35% of the factories have a lower SEC value than the average value (Figure 6).

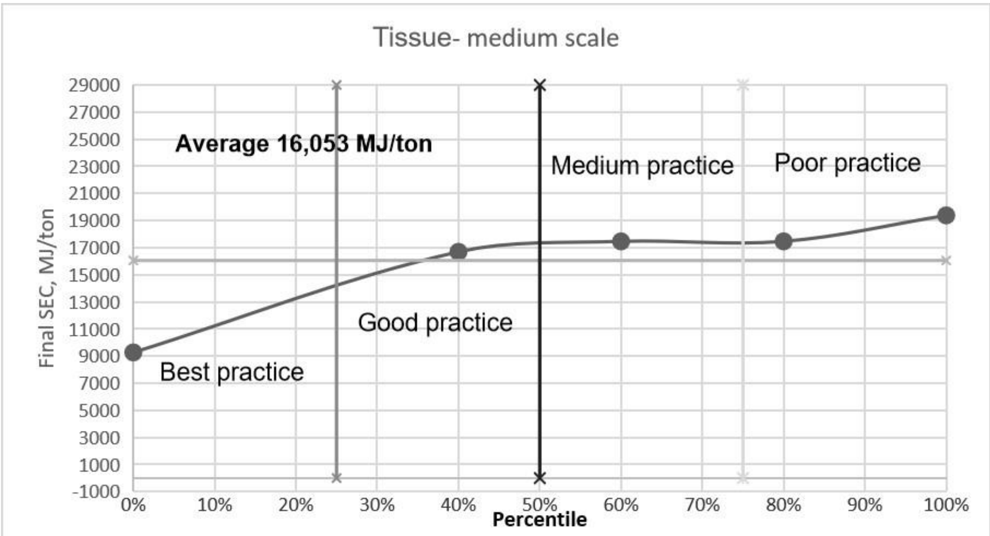

Figure 6. Percentile graph of final specific energy consumption of tissue paper sector—Group 2 (medium scale).

The SEC of group 1 (small factories with production <10,000 tons/year) is lower than that of group 2 (Table 6). This was observed during the preliminary audit that small factories have simple stock preparation steps, and consume less power than medium factories. Some small factories have not been equipped with DIP lines and therefore their energy consumption is lower.

Table 6. Average specific energy consumption by groups of tissue paper sector.

	Average SEC, MJ/ton	Best practice, MJ/ton
Group 1 (small scale)	14,914	5,926
Group 2 (medium scale)	16,503	9,270
Whole subsector	15,438	5,926

3.3.4. Energy consumption benchmarking of printing and writing paper sub-sector

It is noted that each group in this sub-sector has different production processes. The factory in group 1 used deinked pulp along with commercial virgin pulp as raw materials and possesses DIP facilities. The factories in group 2 used only virgin pulp. The group 3 factories were integrated plants in which virgin pulp was self-produced from wood on site.

The survey results showed that the energy consumption of the factories using recycled papers (group 1) or integrated with the Kraft pulping process (group 3) was higher than those using commercial virgin pulp (group 2) (Figure 7).

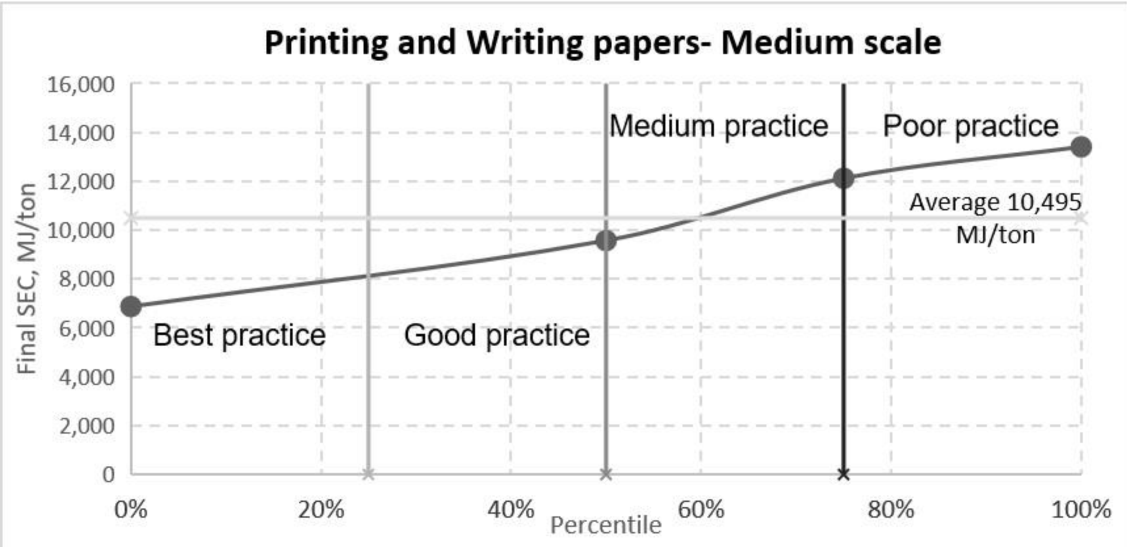

Figure 7. Percentile graph of specific energy consumption of printing and writing paper sector—Group 2 (medium scale).

It has been noted that only group 2 of this subsector with 04 sets of data could be used for benchmarking exercise (Table 7).

Table 7. Average specific energy consumption by groups of factories (printing and writing papers sub-sector).

Group	Number of surveyed factories	Average final SEC, MJ/ton	Production variation
Group 1 (small scale)	1	17,542	Having DIP line
Group 2 (medium scale)	4	10,495	Without pulping and DIP process
Group 3 (large scale)	2	15,138	Integrated Kraft pulping process

3.4. Energy saving potential for the pulp and paper industry of Vietnam

In this section, I estimate the energy saving potential of the pulp and paper industry in Vietnam using different scenarios as follows.

3.4.1. Scenario 1: Moving the average baseline

In this approach, all factories with higher SECs than the sectorial average need to bring down their SECs to the sectorial average value. The new expected SECs of factories will set a new (expected) average value. The difference between the two average values can be considered as the sectoral energy saving potential. In this approach, this potential value can be seen as the target of the energy efficiency strategy/program.

For packaging papers:

The energy saving potential, in this case, was estimated at 19.5% (Figure 8).

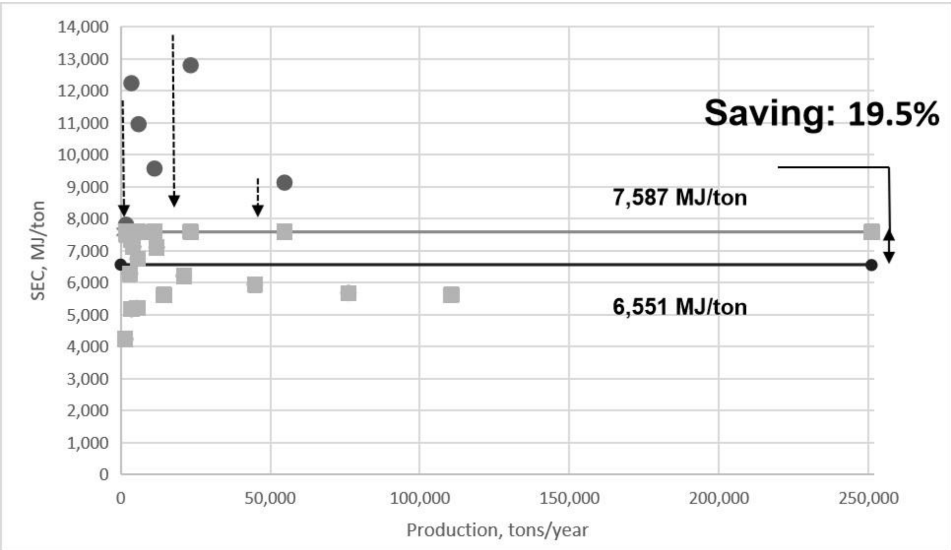

Figure 8. Possible final energy saving potential for the packaging paper sector.

For tissue papers:
The energy saving potential, in this case, was estimated at 11.6% (Figure 9).

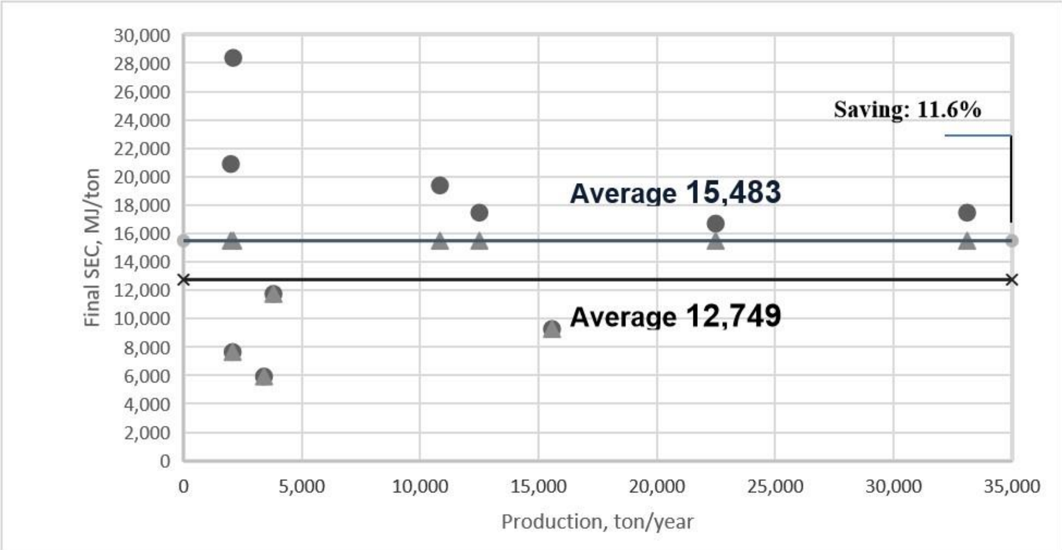

Figure 9. Possible final energy saving potential for the tissue paper sector.

For printing and writing papers:
The energy saving potential, in this case, was estimated at 20% (Figure 10).

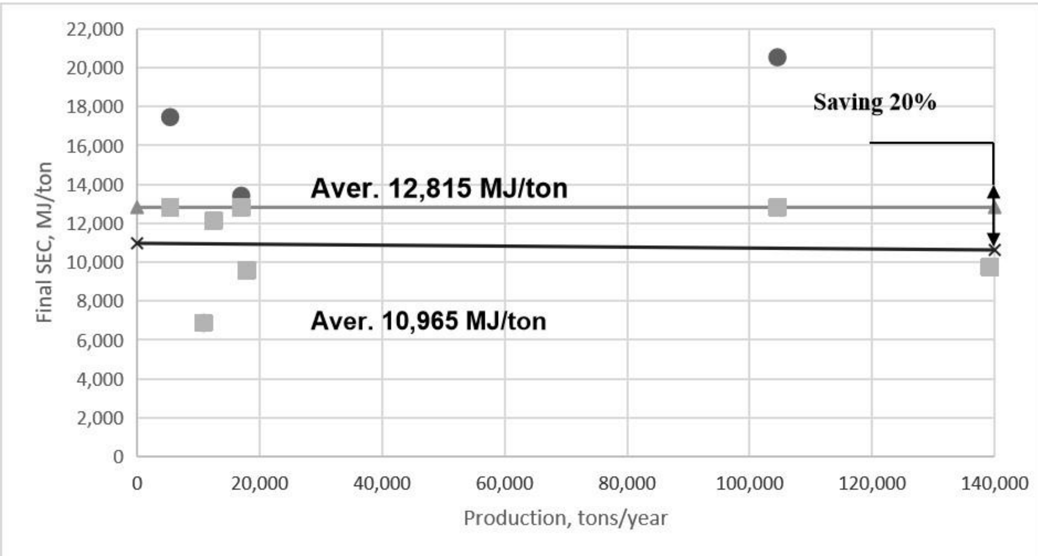

Figure 10. Possible final energy saving potential for printing and writing paper sector.

3.4.2. Scenario 2: Moving the average baseline of scale groups

The factories have been classified into three groups with different SECs. It is noted that small factories have less modern machinery with inadequate maintenance. However, due to their simpler re-pulping process and their product qualities, these factories may not compete with highly invested larger scale factories.

Regarding the similarity in technology, equipment and management of factories in each group (small, medium and big scales) and the relative independence of the evaluation method, the energy saving potential assessment was done for every scale group with the same approach as described in the Scenario 1. The results of the calculation are shown in Table 8.

Table 8. Energy saving potential for each group was calculated by moving the average baseline of the scale group.

Subsector	Energy saving potential (%)			
	Group 1 (Small scale)	Group 2 (Medium scale)	Group 3 (Large scale)	Whole sub-sector
Packaging papers	17.6%	17.6%	19.4%	19%
Tissue papers	22%	7.5%	-	9%
Printing and writing papers	-	11.2%	32.2%	29%

In comparison with the previous approach, this approach provides us a clearer details of energy saving potentials for all sub-sectors of the pulp and paper industry in Vietnam.

4. Discussion

4.1. Main results

In this research, I have provided an energy benchmark for the pulp and paper industry of Vietnam. The main results were summarized as follows.

Energy benchmark

Packaging paper sub-sector: The average SEC of small scale factories is 6,728 MJ/ton; of medium scale factories is 7,872 MJ/ton for large scale factories is 7,809 MJ/ton. The distribution of the final SEC for small scale product categories shows that 50% of surveyed factories have the final SEC lower than the sectorial average. For medium scale factories, 73% of surveyed factories have the final SEC lower than the sectorial average. For large scale factories, 67% of surveyed factories have the final SEC lower than the sectorial average.

Tissue paper sub-sector: The average SEC of small scale factories is 14,914 MJ/ton; of medium scale factories is 16,503 MJ/ton. It is found that the average baseline of medium scale tissue paper factories has fallen in the medium practice, and 60% of the factories have lower SEC values than the average value. The average baseline of medium scale tissue paper factories (group 2) is lowering in good practice, and 35% of the factories have lower SEC values than the average value.

Printing and writing paper sub-sector: The average SEC of small scale factories is 17,542 MJ/ton; for medium scale factories is 10,495 MJ/ton and for large scale factories is 15,139 MJ/ton. However, only group 2 (medium scale factories) can be benchmarked with 4 sets of data. It was found that the average baseline of medium scale tissue paper factories is lower in the medium practice, and 60% of the factories have lower SEC values than the average value.

Despite different settings for doing benchmarks, the results of this study are comparable with the results of Laurijssen, Faaij [20] for several paper products such as tissue paper (SEC = 14.7 GJ/ton). In this research, I was interested in the SEC of the whole process, while Laurijssen, Faaij [20] focused on the average energy consumption for each stage of the production process. In addition, I have also found that the benchmarking results of this research are agreeable and useful for factories surveyed in this research.

Energy saving potentials

The energy benchmark is an important basis for estimating the energy saving potential. In this research, I used two approaches for estimating energy saving potential, but other approaches (such as moving average baseline for each scale group and each quartile) can be used. Two scenarios for determining energy saving potential are summarized as follows.

Scenario 1 is to target the average baseline for all factories. Under this approach, all factories with higher SEC than the sectorial average will try to reduce it to the sectorial average value. Scenario 1 will lead to 13.6% of energy savings for the packaging sub-sector, 17.6% for the tissue paper sub-sector, and 14.4% for printing and writing paper.

Scenario 2 is to target the average baseline based on production capacity scale groups. Under this approach, the energy saving potential assessment is carried out for each scale group (large, medium, and small) with the same approach. Scenario 2 gives more detail on potential energy savings in the three sub-sectors of the pulp and paper industry in Vietnam.

4.2. Implications and limitations

The results are useful for companies in the pulp and paper industry to evaluate their energy performance in comparison with the average of the industry and with other companies in the industry. These results can be used by policymakers as well to propose national energy efficiency policies for lifting the energy efficiency in the pulp and paper industry of Vietnam.

As described before, setting up suitable (energy) SEC levels is crucial for policymakers to promote national energy efficiency. Appropriate SEC values encourage companies to strive and to improve themselves for better energy efficiency. This will help to reduce energy consumption and therefore decrease exhaust emissions in industries, particularly in the pulp and paper industry in this case. This will contribute to the goal of reaching carbon neutral emissions of the government Vietnam in 2050.

However, this study has some limitations that can be improved. In this research, I cannot get data from all factories in the industries and the number of audit factories can be increased to enhance the quality of results.

5. Conclusions

In this paper, I proposed an applicable methodology to establish an energy benchmark for the pulp and paper industry of Vietnam. The SEC was used as the energy indicator to evaluate energy efficiency in the pulp and paper industry. An energy survey and energy audit were used to determine energy benchmarks and energy saving potentials for three main sub-sectors in the pulp and paper industry of Vietnam.

This research established the benchmark SEC values for the pulp and paper industry in Vietnam and estimated the energy saving potentials for the pulp and paper industry in Vietnam as well.

Use of AI tools declaration

The author has not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

The author declares no conflicts of interest.

Author contributions

The corresponding author has done all the work in the paper.

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Appendix

Table A1. Energy benchmarking methodology for the pulp and paper industry of Vietnam [7].

Step	Name	Main content in the methodology
1	Narrow down the range of pulp and paper products for the benchmarking exercise.	The types of product were classified into 3 main product families: 1. Packaging; 2. Tissue; 3. Printing and writing paper.
2	Define system boundary	Boundary: production facility (process), utilities (converting energy into energy carriers), waste treatment facility. The energy used in all areas that are not directly contributing to the production process (office, canteen and other facilities) should not be included within the benchmarking boundary. Energy used for transportation, others production of should not be included.
3	Determine variables and other factors that may affect the energy usage in each sector.	
4	Develop benchmarking comparison table.	
5	Verify the accuracy of the data which formed the basis for arriving at the benchmarked figures/values.	
6	Tabulate the data available in the questionnaire and group the factories as per production capacities.	Per group of products, the factories are classified according to their production scales: - Small scale (<10,000 tons per year), - Medium scale (10,000–50,000 tons per year), - Large scale (above 50,000 tons per year). The capacity of the subsectors classified by products to be benchmarked would be larger than 50% of the capacity of the subsectors. Specific energy consumption will be applied in the benchmarking in three forms as: - Overall final specific energy consumption (MJ/ton), - Specific thermal energy consumption (MJ/ton), - Specific electricity consumption (MJ/ton).
7	Conduct preliminary audits to the shortlisted factories, and re confirm the data and also identify the energy saving potential.	Identify factors which are necessary for the normalization and extrapolation during the benchmarking process. Identify possible energy saving opportunities that are used for extrapolating in the sectorial energy saving potential assessment.
8	Data analysis and Disseminate the results to the industry and assess the energy saving potential for the subsector (Identification of energy saving potential).	Energy saving potential can be assessed by the below method: - Use $SEC_{average}$ value as benchmarking. All factories with SEC above the present $SEC_{average}$ will be able to bring their SEC down to the present $SEC_{average}$. - Based on this, calculate future $SEC_{average}$. Energy saving potential of the sector is calculated by taking the difference between present $SEC_{average}$ and future $SEC_{average}$ multiplies by total annual production of the sector. - Using percentile charts evaluate the surveyed factories' energy performance, by defining how much % of factories are best, good, medium, and poor performance.

Table A2. Energy conversion factors [7,8].

No	Type	Unit	toe/unit	Final MJ/unit	Primary MJ/unit
1	Electricity	kWh	0.0001543	3.60	6.46
2	Dust coal 1,2	ton	0.7	29,309.00	29,309.00
3	Dust coal 3,4	ton	0.6	25,122.00	25,122.00
4	Dust coal 5,6	ton	0.5	20,935.00	20,935.00
5	DO (Diesel oil)	ton	1.02	42,707.40	42,707.40
		1000 litter	0.88	36,845.60	36,845.60
6	FO (Fuel oil)	ton	0.99	41,451.30	41,451.30
		1000 litter	0.94	39,357.80	39,357.80
7	LPG	ton	1.09	45,638.30	45,638.30
8	Biomass (Rice husk)	ton	0.3	12,600	12,600
9	Steam (6 bar)	ton		2,755.46	3,673.95
10	Steam (7 bar)	ton		2,761.00	3,681.33
11	Steam (9 bar)	ton		2,772.13	3,696.17