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2030 Target for Energy Efficiency and Emission Reduction in the EU Paper Industry

Shuangjie Li [1], Li Li [1] and Liming Wang [1,2,*]

[1] School of Economics and Management, Beijing University of Technology, Beijing 100024, China; lishuangjie@emails.bjut.edu.cn (S.L.); lili@emails.bjut.edu.cn (L.L.)
[2] Irish Institute for Chinese Studies, University College Dublin, D04 V1W8 Dublin, Ireland
* Correspondence: liming.wang@ucd.ie

Abstract: Improving energy efficiency is an effective way to address the issues of economic development, energy saving and emissions reduction. For any important industries it is therefore necessary to measure energy efficiency and set a practical target for it. In this paper, we use CCR, SBM and energy intensity to measure the energy efficiency of the paper industries of 22 EU countries. Results indicate that the SBM and CCR efficiency value is more meaningful for policy makers than that of energy intensity, as measurement results of energy intensity deviate from reality and economic efficiency. The CCR and SBM have roughly the same fluctuation trends and the average SBM energy efficiency value is 0.71, always 10 percent lower than CCR model, as it takes simultaneous account of both the optimal input-output and has more discriminatory power in efficiency measurement. Furthermore, EU policy makers could improve energy efficiency by raising energy prices. As for the 2030 EU target of energy saving and emission reduction, the EU should pay more attention to five major paper producers: Finland, Sweden, Germany, the United Kingdom and Italy.

Keywords: TFEE; EU paper industry; SBM; energy saving; emission reduction; 2030 target

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1. Introduction

According to the BP Statistical Review of World Energy, primary energy consumption grew at a rate of 2.9% in 2018, almost double its 10-year average of 1.5% per year and the fastest since 2010. Specifically, in 2018 the primary energy consumption worldwide was 13,864.9 million tonnes of oil equivalent (Mtoe). At the same time, carbon emissions rose at a rate of 2.0%, the highest rate for seven years, reaching 33,890.8 million tonnes in 2018, as a result of increased energy consumption, moving even further away from the accelerated transition envisaged by the Paris Climate Goals [1].

In BP's 2019 economic analysis report, they estimate that energy consumption growth can be traced back to weather-related impacts, as households and businesses have increased demand for cooling and heating to cope with unusually hot and cold weather. That is to say, the increase in extreme weather leads to an increase in energy consumption, which in turn leads to an increase in carbon emissions. Greenhouse gas emissions are the cause of extreme weather. It is worth paying attention to a vicious circle among the three, i.e., the cyclical relationship among energy consumption, greenhouse gas emissions and extreme weather. The world is on an unsustainable path: the longer carbon emissions continue to grow, the more difficult and costly it will be to adjust to net zero carbon emissions [1].

Obviously, excessive energy consumption has caused great damage to the environment and the climate, and energy use is a major source of greenhouse gas emission [2,3]. On the other hand, it is hard to reduce energy consumption considering the increase in energy demand due to the development of the world economy. In this context, improving energy efficiency has become a widely recognized way to achieve the SDGs, because it can address economic development, energy saving and environmental issues simultaneously.

As an essential production factor, energy plays an important role in many sectors. The key sectors for tracking energy use are transport, services, manufacturing and the residential sector. Among them, the paper industry is considered one of the most energy-intensive subsectors in the manufacturing sector [4].

In this paper, we investigate the European Union (EU) paper industry as a subsector of energy consumption. According to the Confederation of European Paper Industries (CEPI), in terms of total paper production around the world, Asian, North America, and European paper outputs account for 40%, 20% and 25% of the world's total, respectively [5]. Within the EU, the energy consumption of the paper industry in EU countries accounted for 14.77% of the total manufacturing consumption in 2017. Therefore, improving the energy efficiency in the paper industries in EU countries is of great significance to European energy saving and emission reduction goals.

The EU paper industry has been working hard to improve its energy efficiency and reduce emissions with notable results in recent years. The most prominent policies to reduce emissions in the EU include the Emission Trading System (ETS) and the 2012 Bioeconomy Strategy. The purpose of these policies is to ensure fossil materials to be replaced by sustainable alternatives, which is reflected in the EU Horizon 2020 research framework programme. This has already achieved a 27% reduction in carbon emissions from 2005 to date, which is believed far from enough [5]. Also, the EU has developed specific policies to achieve sustainable development, including 2030 environmental, energy and climate targets, which were adopted by the European Council in October 2014 and then revised upwards in 2018.

Specifically, the 2030 climate and energy framework includes EU-wide targets and policy objectives for the period 2021 to 2030 [6]. Key targets for 2030 are:

- At least 40% cuts in greenhouse gas emissions (from 1990 levels)
- At least 32% share for renewable energy
- At least 32.5% improvement in energy efficiency.

In this paper, CCR and SBM models are employed to measure the total factor energy efficiency (TFEE) of the paper industries in 22 EU countries. This is followed by a comparative analysis of the results as well as energy intensity. To the best of our knowledge, there are only two papers published to date in the area of energy efficiency for the paper industry in Europe, both of which focused on papermaking enterprises in Sweden and Germany. Therefore, this study fills the gap in this field by examining energy efficiency of the paper industry in 22 EU countries and presents policy implications for EU decision makers. In addition, a more complete set of input-output indicators has been employed in this paper to measure total factor energy efficiency. It is believed that the measuring results in this paper are more reliable and accurate. Empirical results indicate that the EU paper industry has great potentials for energy saving and emission reduction of 33% and 71% per year respectively, which is much higher than the 2030 energy saving target of the EU. Therefore, the EU paper industry has potential to achieve its 2030 target.

2. Literature Review

In view of the important role of energy efficiency in economic development, some in-depth research on energy efficiency has been conducted by scholars in recent years. At present, the measurements of energy efficiency can be roughly divided into two categories: Single Factor Energy Efficiency (SFEE) and Total Factor Energy Efficiency (TFEE).

2.1. SFEE

2.1.1. Energy Intensity (EI = E/GDP)

Energy intensity, also known as energy consumption per unit of output, is the commonly used indicator of SFEE and refers to the amount of energy consumed per unit of output of a country or industries over a given period of time. At the national level, energy intensity is the ratio of total domestic primary energy consumption or final energy consumption to gross domestic product. This index is easy to calculate and convenient for comparative analysis among different subjects. Therefore, it is widely used by scholars and government departments as a key indicator for macro-economic policies.

2.1.2. Energy Productivity (EP = GDP/E)

Energy productivity is the reciprocal of energy intensity, which refers to how much economic output can be produced per unit of energy consumption.

Energy efficiency is to produce the same number of services or useful outputs with less energy. SFEE only measures the proportional relationship between energy input and gross value added and there has been widespread criticism of using energy intensity for measuring energy efficiency [7]. Energy alone cannot produce any outputs. Energy must be combined with other inputs to produce outputs [8]. The main problem with energy/GDP, as pointed out by Wilson et al. [9], is that it does not measure the underlying technical energy efficiency, which can be misleading. As SFEE measurements, both energy intensity and energy productivity only take energy into account, and ignore capital, labor and other inputs. At the country or region level, some industries have alternatives among a variety of inputs. With more capital, labor and other inputs, the energy input can be reduced, thereby improving energy productivity, but this doesn't mean an improvement in energy efficiency or economic efficiency for the regions or the industries.

2.2. TFEE

Energy efficiency improvement relies on total-factor productivity improvement [10]. Unlike SFEE, which only considers a single input variable and a single output variable, the TFEE indicator is calculated under the framework of a variety of input and output variables, fully considering the results of interaction of various factors in production activities and thus overcoming the deficiency of the SFEE method to a certain extent. The dominant idea of TFEE is to minimize input when output remains unchanged or maximize output when input remains unchanged. As for the measurement of energy efficiency, TFEE is the ratio between the optimal energy input and the actual energy input, and it is a relative efficiency index. The TFEE index was first proposed by Hu and Wang [8]. Since then, it has been widely developed and applied. According to development of the total factor framework, it is roughly divided into three stages.

The first stage is a total factor framework without undesirable outputs. Hu and Wang [8] take actual output as the only variable without taking the impact on the environment into account. Taking capital, labor and energy consumption as input variables and real GDP as output variables, Hu and Kao [11] use a DEA model to measure the energy-saving targets of 17 APEC economies and find that the average value in 2000 was 13.70%. Zhao et al. [12] used capital, labor, energy consumption and industrial added value for each sector in 10 provinces from eastern, central and western regions of China to investigate TFEE change at provincial sector level during the period 1997–2007. The results in that study indicate that over the time, TFEE of each sector has improved in general. In addition, Honma and Hu [13] measured the TFEE of 47 regions in Japan for the period 1993–2003; Zhang et al. [14] explored total-factor energy efficiency and change trends in 23 developing countries by applying DEA window analysis. Many other scholars like Mousavi-Avval et al. [15], Blomberg et al. [16] and Song et al. [17,18] also employed the same total-factor framework to measure energy efficiency.

The second stage is an ecological total factor framework. On the basis of the first stage, it considers the impact of production on the environment, and treats the emission of production as the undesired output. It conforms to the actual production process as well as to the concept of sustainable development. Therefore, it is an improvement and development from the total factor framework in the first stage. Zhou and Ang [19] and Yeh et al. [20] take account of desirable outputs together with undesirable outputs in their models; Li and Hu [21] also computed the ecological TFEE of 30 regions in China for the period 2005–2009 using a slack-based model. The ecological TFEE is constructed as the ratio of the target energy input suggested from the SBM model with undesirable outputs of the actual energy input in a region. Özkara et al. [22] investigated the total-factor energy efficiency scores of manufacturing industries in 26 regions in Turkey between the years 2003 and 2012, using four DEA models supported by a total-factor framework taking CO_2 emission as undesirable output. Emrouznejad and Yang [23] used a novel Malmquist-Luenberger productivity index based on directional distance function to address the relative efficiency and productivity of a group of homogenous DMUs as well as to evaluate CO_2 emissions reduction in Chinese light manufacturing industries. Undesirable outputs are also used by Camioto et al. [24]; Choi et al. [25]; Liu and Lin [26,27]; Perez et al. [28]; Sahoo et al. [29] in their studies.

Most of the papers related to TFEE, reviewed above, follow the framework proposed by Hu and Wang [8] and Li and Hu [21], i.e., capital, labor and energy consumption are taken as input variables, added value is taken as a desirable output, with or without emissions as undesirable outputs. Following the principle that the input indicators should be consistent with the output indicators, Li and Li [30] propose a revised input-output framework of TFEE in which the output indicator corresponding to capital, labor, energy consumption and other intermediate inputs is gross output rather than the value added output. Therefore, the total factor framework for measuring energy efficiency should take gross output as the desirable output. In their study, undesirable output is composed of waste residue, emission and waste water. This recently developed framework could be classified as the third stage of TFEE with different input-output indicators.

3. Method and Data

The data envelopment analysis (DEA) method proposed by Charnes, Cooper and Rhodes (CCR) [31] in 1978 to calculate TFEE is employed in this study. DEA is a method for evaluating the relative efficiency of several decision-making units (DMUs) with the same type of inputs and outputs, and does not require the form of a production function to be set in advance. This method is based on sample input-output data and aims to find a piecewise linear production frontier. By calculating the distance between the actual production point and the production frontier of all DMUs, the efficiency of each DMU is measured. This method is used to measure the TFEE for the paper industries in EU countries. The CCR model is one of the basic DEA models. With the development of modeling, a variety of DEA models have emerged, including the SBM model.

3.1. CCR and SBM Model Revision of Indicator Framework

The CCR model assumes that the return to scale is constant, that is, all DMUs have the same optimal scale frontier. Let's say there are I DMU, and each DMU has N inputs and M outputs. The input and output of the ith DMU are expressed by the column vectors xi and qi respectively. The N × I input matrix X and M × I output matrix Q represent all the data of the ith DMU. Then the input-oriented CCR model with constant return to scale is:

$$\begin{gathered} \mathrm{Min}_{\theta,\,\lambda}\ \theta \\ \mathrm{st}\ -\mathrm{q}_i + \mathrm{Q}\lambda \geq 0 \\ \theta_{xi} - \mathrm{X}\lambda \geq 0 \\ \lambda \geq 0 \end{gathered} \tag{1}$$

In this model, production technology is defined as T = {(x, q):q ≤ Qλ, x ≥ Xλ}; λ represents a constant vector. θ represents the efficiency value of the i-th DMU, which satisfies that θ ≤ 1. When θ is equal to 1, it indicates that this DMU is on the frontier and is technically effective. Otherwise, it is technically ineffective.

The traditional DEA model is basically radial. The influence of slack variables on energy efficiency cannot be measured, so the efficiency value of the DMUs may be overestimated. Radial measure of efficiency only considers proportional reduction of inputs and hence it lacks discriminatory power and is not able to provide a comprehensive measure of efficiency [30]. While radial-based models can only deal with a reduction in the proportion of inputs and outputs, when there is a non-zero slack of inputs and outputs, such models will overestimate the efficiency of DMUs. Therefore, there will be a certain deviation between the calculated efficiency and the actual efficiency.

To this end, Tone [32] proposed SBM models to solve this problem. The SBM model directly incorporates slack variables into the objective function, which solves the problem of slack. On the other hand, the SBM model is a non-radial measurement method in the DEA model, thereby avoiding the deviation in energy efficiency measurement caused by radial. Therefore, the SBM model can better reflect the essence of efficiency than other models. The following is the SBM model, where ρ represents the technical efficiency:

$$\begin{aligned} \min\rho &= \frac{1-\left(\frac{1}{m}\right)\sum_{i=1}^{m}\frac{s_i^-}{x_{i0}}}{1+\left(\frac{1}{s}\right)\sum_{r=1}^{s}\frac{s_r^+}{y_{r0}}} \\ \text{st } x_0 &= X\lambda + s^- \\ y_0 &= Y\lambda - s^+ \\ \sum_{j=1}^{n}\lambda_j &= 1 \\ \lambda \geq 0,\ s^- &\geq 0,\ s^+ \geq 0 \end{aligned} \tag{2}$$

x_0 and y_0 are the input vector and output vector of a certain DMU respectively; s_i^- is the slack value of i-th input, and s_r^+ is the slack value of r-th output.

According to Hu and Wang's [8] definition of TFEE, the calculation formula is as follows:

$$\text{TFEE} = \frac{\text{Target energy consumption}}{\text{Actual energy consumption}}, \tag{3}$$

Target energy consumption is equal to actual energy consumption minus energy adjustment amount. In the CCR model, energy adjustment amount includes proportional reductions in energy consumption and energy-related slack. In the SBM model, the energy adjustment amount is the total energy slack. The calculated energy adjustment amount is an invalid part of the actual energy consumption and it is also the amount of potential energy savings while keeping existing output constant. The greater the adjustment of energy input, the lower the energy efficiency of the DMU, i.e., more energy input can be saved. If the adjustment of energy input is 0, that is, target energy consumption is equal to the actual energy consumption, indicating that the DMU is located on the frontier and is efficient.

3.2. Data Revision of Indicator Framework

In the existing literature on TFEE, there is duplication or omission in the selected input-output indicators, which do not conform to the theory of production economics and actual production practice. The most commonly used input-output indicators are capital, labor and energy as inputs and added value as an output indicator. Some scholars consider the impact of production on the environment and added undesirable output to the output indicator, while some scholars consider other intermediate inputs, but most of the existing literature fails to avoid duplication and omission of indicators. The main problems are as follows:

(1) Other intermediate inputs are not often included as input indicators. The sum of energy consumption and other intermediate input is an intermediate input in production. Because inputs such as capital, labor and energy alone cannot complete overall production and create output. Therefore, other intermediate input is indispensable.

(2) The desired output should be gross output, not added value (both GDP and industrial value-added are added value). According to economic theory, the transferred and newly created value of capital and labor input after participating in production constitute added value. Value added does not consider the use of intermediate consumption (the sum of energy consumption and other intermediate inputs), and

only relates to capital and labor. Therefore, in order to ensure the consistency of the accounting scope and value composition in the production process, that is, to keep the input and output indicators consistent, if the output is added value, the corresponding input indicators should use capital and labor, but not energy. Gross output is the sum of value of all goods and services produced by the production sector in a given period of time, including both added value and intermediate consumption. As shown in formula (4), GVA represents gross value added, which is roughly equal to GDP and can be expressed as the difference between gross output and intermediate consumption. In the process of national economic accounting, value added (GDP) should be used to avoid double counting if it is used for distribution purposes. If it is used for production purposes, however, gross output (GO) should be used. Although there is a problem of double counting in most cases, it will not affect the results much in the efficiency analysis here; otherwise, replacing GO with added value (GDP) will underestimate the production scale by more than 50%, thus resulting in an underestimation of overall economic activity by 50%. Therefore, when measuring energy efficiency, the output indicator corresponding to capital, labor, energy, and other intermediate inputs is gross output. Gross output is more comprehensive, and focuses on the issue of resource consumption and therefore meets the requirements of sustainable development:

$$\text{GO} - \text{intermediate consumption} = \text{GVA} \tag{4}$$

Therefore, considering the impact of environmental pollution, the more comprehensive TFEE indicator framework constructed in this paper is as follows: capital, labor, energy consumption, other intermediate inputs, gross output and undesirable output.

3.3. Data

In this paper, we examine the paper industries in 22 EU member states from 2008 to 2016 (France, Spain, Cyprus, Luxembourg, Malta and Croatia were excluded due to the absence of relevant data). The main data source is Eurostat, with the exception of the depreciation rate which is from the EU KLEMS database. All value variables are deflated with the 2010 price as the base year price. Main variables employed in this paper are as follows:

(1) Capital, the capital stock is used as capital input. Since there are no statistics on capital stock, the perpetual inventory method pioneered by Goldsmith in 1951 is adopted to estimate the annual value from 2008 to 2016 by using the following equation:

$$K_t = K_{t-1} \times (1 - \delta_t) + I_t \tag{5}$$

where, K_t and K_{t-1} denote the capital stock of current year and previous year respectively, δ_t is the depreciation rate, and It is current investment. In this paper, fixed capital consumption in 2008 divided by the depreciation rate is used as the capital stock for the base year and gross investment in tangible goods is used as annual investment. As for the depreciation rate in EU paper industries, it is a fixed value of 10.6%.

(2) Labor, the labor input indicator selected in this paper is personnel costs, which are defined as the total remuneration, in cash or in kind, payable by an employer to an employee in return for work done by the latter during the reference period.

(3) Energy consumption, the final energy consumption in the paper industries is used as energy input.

(4) Other intermediate consumption, is calculated as the value of total intermediate consumption minus the value of energy consumption.

(5) Output, corresponding to capital, labor, energy consumption and other intermediate consumption, gross output of paper industries is selected as desirable output. For the undesirable output, we only use waste residue and greenhouse gas as the data for

wastewater is not available. Greenhouse gas is calculated by the sum of CO_2, N_2O, CH_4, HFC, PFC, SF_6, NF_3 in CO_2 equivalents.

Paper industries are considered to be one of the energy-intensive sectors. As we mentioned in the introduction, the European paper industries sector accounts for almost a quarter of the world's paper industries, both in production and consumption [5]. NACE Rev.2 is the European industries standard classification, which is the same as International Standard Industrial Classification of All Economic Activities Revision 4 (ISIC, Rev.4). According to the classification of economic activities in NACE rev.2, under section C manufacturing, there are two sub-industries related to papermaking, namely, division 17-Manufacture of paper and paper products, and division 18- Printing and reproduction of recorded media. A more detailed breakdown is presented in Table 1. The paper industries sector is defined in this paper as the sum of the two sub-industries of manufacture of paper and paper products and the printing and reproduction of recorded media. Descriptive statistics on the input and output of the paper industries in the EU are shown in Tables A1 and A2, respectively.

Table 1. Detailed classification in paper industries.

Division	Group	Description
17		Manufacture of paper and paper products
	17.1	Manufacture of pulp, paper and paperboard
	17.2	Manufacture of articles of paper and paperboard
18		Printing and reproduction of recorded media
	18.1	Printing and service activities related to printing
	18.2	Reproduction of recorded media

4. Empirical Efficiency Measurement

In this paper, both input-oriented CCR model and SBM are employed to measure TFEE. In the CCR model, all inputs must adjust proportionally without reducing output, while the SBM model is a non-radial DEA method, which directly deals with the problem of input and undesirable output redundancy as well as desirable output deficiency. Therefore, the SBM model has more advantages in measuring energy redundancy as well as optimal energy input. The energy efficiency results of the CCR model are shown in Table 2 below. Overall, average energy efficiency value shows an upward trend with an improvement of 10.8%, from 76.3% in 2008 to 87.1% in 2016. In terms of all countries' average during the period, the energy efficiency of EU paper industries was found to be 81.9%, which indicates that it would be possible to make all the inputs decrease proportionally by 18.1% while keeping the original output unchanged. Specifically, nine countries out of 22 can reduce all inputs proportionally by even more than the average level of 18.1%. It can be observed that four of these countries, respectively Ireland, Latvia, Lithuania and Slovakia, are always energy efficient, with energy efficiency of 1 per year. The lowest efficiency value was Finland, with the highest saving potential of 57.3%. The reason is that Finland has high forest coverage, so wood processing related industries are very developed, but its paper industry has always been known for its excessive energy consumption and heavy pollution. Besides, countries like Estonia and Sweden can also reduce energy consumption by about 40%.

By finding the maximum distance to frontier, SBM based TFEE of 22 EU countries are presented in Table 3. The SBM model has better discriminatory power in energy efficiency measurement than the CCR model and will provide maximum potential for energy saving through a non-radial reduction in all inputs [33]. Overall, the average TFEE value is 70.3%, indicating that these 22 countries still have 29.7% potential for savings, which accounts for a large part of the total energy consumption in Europe, equivalent to 100,000 Gigawatt-hours (Gwh) of electricity. From 2008 to 2010, energy efficiency increased dramatically, from 62% to 79% due mainly to the improved performance and economic recovery after the

2008 financial crisis. The decline in energy efficiency that began in 2011 was caused by the negative impact of a Europe-wide economic downturn on European paper industries [5]. Following a gradual decrease between 2011 and 2014, energy efficiency increased between 2014 and 2016. The increase could partly be attributed to good economic performance since 2014 and low oil prices. From the perspective of individual countries, energy efficiency varies widely, from 0.331 to 1. Ireland, Latvia, Lithuania and Slovakia have the most efficient paper industries, while Slovenia, Finland, Estonia, Austria and Belgium all have low energy efficiency values, with more than 50% energy reduction space.

Table 2. Annual TFEE of 22 EU countries under the CCR model.

Country	Year									Average
	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Belgium	0.763	0.795	0.799	0.711	0.697	0.717	0.755	0.787	0.815	0.760
Bulgaria	0.276	0.647	0.323	1.000	1.000	1.000	0.932	0.795	0.899	0.764
Czechia	0.701	0.790	0.776	0.551	0.819	0.844	0.892	0.892	0.901	0.796
Denmark	0.918	0.851	0.929	0.810	0.887	0.871	0.886	0.865	0.927	0.883
Germany	0.773	0.796	0.827	0.788	0.707	0.765	0.638	0.662	0.642	0.733
Estonia	0.524	0.463	0.609	0.656	0.418	1.000	0.609	0.599	0.433	0.590
Ireland	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Greece	0.998	0.880	0.961	0.908	0.840	0.845	0.838	0.882	1.000	0.906
Italy	0.795	0.819	0.972	0.915	0.814	0.818	0.849	0.841	0.986	0.868
Latvia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Lithuania	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Hungary	0.775	0.776	0.984	0.869	0.825	0.834	0.852	0.853	0.873	0.849
Netherlands	0.790	0.825	0.882	0.882	0.813	0.788	0.797	0.786	0.934	0.833
Austria	0.681	0.805	0.777	0.713	0.644	0.678	0.650	0.716	0.837	0.722
Poland	0.712	0.741	0.772	0.411	1.000	1.000	1.000	1.000	1.000	0.848
Portugal	0.596	0.743	0.833	0.611	0.787	0.823	1.000	1.000	1.000	0.821
Romania	1.000	1.000	1.000	1.000	1.000	1.000	0.947	0.875	0.863	0.965
Slovenia	0.771	0.782	0.714	0.713	0.755	0.759	0.801	0.810	0.832	0.771
Slovakia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Finland	0.385	0.409	0.366	0.354	0.404	0.423	0.444	0.498	0.562	0.427
Sweden	0.472	0.470	0.564	0.575	0.527	0.601	0.643	0.689	0.664	0.578
United Kingdom	0.859	0.891	0.960	0.872	0.852	0.873	0.877	1.000	1.000	0.909
Average	0.763	0.795	0.820	0.788	0.809	0.847	0.837	0.843	0.871	0.819

Table 3. Annual TFEE of 22 EU countries under SBM model.

Country	Year									Average
	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Belgium	0.403	0.777	0.547	0.455	0.348	0.348	0.235	0.587	0.617	0.480
Bulgaria	0.185	0.511	0.439	1.000	1.000	1.000	0.872	0.646	0.776	0.714
Czechia	0.327	0.603	0.541	0.436	0.294	0.305	0.723	0.690	0.773	0.521
Denmark	1.000	0.919	0.966	0.969	0.851	0.828	0.741	0.648	0.919	0.871
Germany	0.515	0.735	0.851	0.683	0.459	0.403	0.334	0.327	0.543	0.539
Estonia	0.370	0.397	0.603	0.416	0.338	1.000	0.211	0.204	0.262	0.422
Ireland	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Greece	1.000	1.000	1.000	1.000	0.684	0.640	0.674	0.772	1.000	0.863
Italy	0.659	0.947	1.000	0.970	0.555	0.536	0.480	0.490	0.726	0.707
Latvia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Lithuania	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Hungary	0.654	0.603	1.000	0.808	0.329	0.356	0.234	0.470	0.509	0.551
Netherlands	0.667	0.714	1.000	0.963	0.630	0.502	0.594	0.617	0.935	0.736

Table 3. *Cont.*

Country	Year									Average
	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Austria	0.312	0.674	0.505	0.391	0.292	0.282	0.227	0.499	0.606	0.421
Poland	0.339	0.531	0.763	0.410	1.000	1.000	1.000	1.000	1.000	0.783
Portugal	0.497	0.691	0.833	0.677	0.732	0.922	1.000	1.000	1.000	0.817
Romania	1.000	1.000	1.000	1.000	1.000	1.000	0.935	0.404	1.000	0.927
Slovenia	0.288	0.657	0.407	0.338	0.261	0.282	0.213	0.311	0.224	0.331
Slovakia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Finland	0.312	0.329	0.396	0.372	0.361	0.520	0.388	0.432	0.429	0.393
Sweden	0.421	0.420	0.535	0.563	0.523	0.774	0.524	0.539	0.524	0.536
United Kingdom	0.691	1.000	1.000	0.858	0.715	0.724	0.652	1.000	1.000	0.849
Average	0.620	0.750	0.790	0.741	0.653	0.701	0.638	0.665	0.766	0.703

For comparative analysis with TFEE, we also used available data from 2008 to 2016 to estimate SFEE: energy intensity. The smaller the value of energy intensity, the higher the efficiency. At a specific industry level, energy intensity is equal to the ratio of energy consumption to industry's added value, with the estimated results shown in Table 4. Energy consumption is converted into electricity, and the unit is Gigawatt-hour. It can be seen from Table 4 that the average energy intensity of 22 countries shows an overall upward trend, indicating a decline in SFEE. The average value is 5.8, which means that for every one million euros increase in the output of the paper industries, an average of 5.8 Gigawatt-hour of energy is required. From a national perspective, energy intensity varies widely, with the lowest being Ireland, at 0.5; the highest being Finland, at 19.69. Overall, the energy intensity of the paper industries fell in 12 of the 22 member countries, indicating improved efficiency. The largest fall in energy intensity was recorded in Czechia (−0.93%), followed by Estonia (−0.75%) and Netherlands (−0.74%). Among the remaining 10 Member States where energy intensity increased from 2008 to 2016, the highest increase was registered in Finland (+3.16%), followed by Bulgaria (+3.12%), Portugal (+1.83%).

Table 4. Energy intensity.

Countries	Year									Average
	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Belgium	3.65	4.22	4.22	3.73	3.71	4.14	4.01	4.07	4.46	4.02
Bulgaria	9.91	4.32	10.80	11.35	11.30	13.41	12.20	13.95	13.03	11.14
Czechia	6.16	6.37	5.74	5.91	6.31	6.40	6.13	5.77	5.23	6.00
Denmark	1.36	1.62	1.86	1.54	1.17	1.36	1.08	1.17	1.10	1.36
Germany	3.91	4.18	4.14	3.97	3.64	3.73	3.73	3.57	3.49	3.82
Estonia	5.48	6.52	6.33	6.10	5.44	5.24	5.07	5.20	4.73	5.57
Ireland	0.40	0.50	0.52	0.52	0.49	0.51	0.48	0.53	0.58	0.50
Greece	1.33	1.46	1.93	1.83	2.00	2.42	2.56	2.41	1.45	1.93
Italy	2.91	3.06	2.85	2.59	2.75	2.46	2.71	2.96	2.68	2.77
Latvia	1.01	1.53	1.29	1.21	0.96	1.02	0.65	0.63	0.61	0.99
Lithuania	1.48	2.50	3.24	2.20	1.50	1.53	1.20	0.99	1.12	1.75
Hungary	3.61	3.14	3.36	3.57	4.06	4.56	4.63	4.48	4.74	4.02
Netherlands	2.63	2.27	2.40	2.24	2.36	2.28	1.98	1.90	1.89	2.22
Austria	6.59	7.02	6.97	6.32	5.91	6.45	6.32	6.29	6.48	6.48
Poland	6.09	5.56	5.42	5.06	4.89	5.86	5.40	5.30	5.52	5.46
Portugal	8.98	9.91	9.82	10.16	11.38	11.73	10.89	10.59	10.81	10.47
Romania	1.39	1.04	2.52	1.06	1.63	1.68	2.50	2.66	2.64	1.90
Slovenia	7.29	7.47	7.27	6.74	6.90	7.05	6.65	6.70	7.07	7.02
Slovakia	12.69	13.96	13.38	14.09	10.04	11.57	12.37	15.22	13.70	13.00
Finland	17.52	22.54	19.12	19.95	19.27	19.15	18.84	20.15	20.68	19.69
Sweden	15.63	16.69	14.96	15.27	14.93	15.59	10.68	16.94	16.15	15.20
United Kingdom	2.45	2.17	2.10	2.14	2.21	2.24	2.20	1.96	2.18	2.18
Average	5.57	5.82	5.92	5.80	5.58	5.93	5.56	6.07	5.92	

As shown in Figure 1, three trend lines representing average efficiency for TFEE-CCR, TFEE-SBM and EI are generally upward. Among them, the energy efficiency estimated by CCR model is 10% higher on average than that of SBM model, albeit the trend is roughly the same. As shown in Table 5, TFEE under CCR and SBM model have significant correlation with the correlation coefficient of 0.837. Based on this observation, it is believed that SBM has a more discriminatory power and hence provides efficiency scores lower than those of CCR measurement of efficiency. Because SBM measures not only the decrease of input, but also the increase of output, it directly aims at maximizing the average slack. Therefore, when there is no output slack, the efficiency values measured by SBM and CCR are the same. When there is output slack, the CCR model would overestimate energy efficiency to some extent. On the one hand, SBM TFEE can provide a smaller energy efficiency score, that is, a greater potential for saving. On the other hand, SBM TFEE can directly show how much energy is wasted, so we believe that SBM efficiency is more suitable for policy makers. In addition, the trend line of energy intensity is similar to the trend of TFEE, but its fluctuation is more drastic. Because the greater the energy intensity, the less the energy efficiency, SFEE represented by energy intensity is opposite to TFEE and is inconsistent with the actual situation: SFEE declined in the economic recovery stage after the financial crisis in 2008 and the economic boom stage in 2014, while it increased in the economic downturn in Europe in 2011. As previously mentioned, energy intensity represents only the proportional relationship between gross value added and energy consumption, and it does have inevitable defects in measuring energy efficiency.

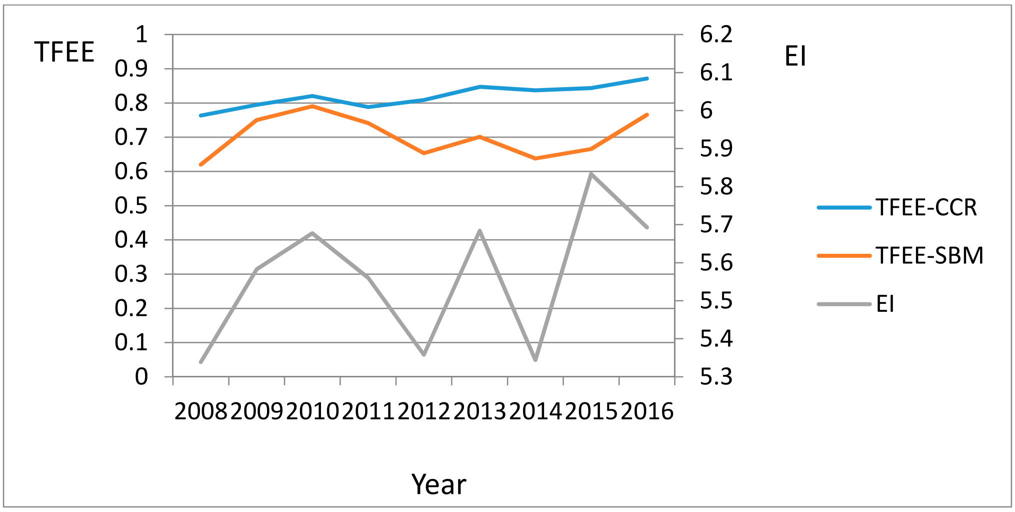

Figure 1. Average efficiency trend from 2008 to 2016.

Table 5. Annual TFEE of 22 EU countries under SBM model.

	TFEE (CCR)	TFEE (SBM)
TFEE (CCR)	1	0.837 **
TFEE (SBM)	0.837 **	1

Note: ** mean extremely correlation at $p < 0.01$.

According to the results of Tables 2 and 3, TFEE values for Estonia indicate a large jump between 2012 and 2013. In the CCR model, TFEE for these two years are 0.418 and 1, respectively. This is caused by overall efficiency of radial adjustment, which was 0.887 in 2012 and 1 in 2013. On the other hand, this is caused by the slack of non-radial adjustment, which was 84 in 2012, while 0 in 2013 due to the overall efficiency value of 1. In the SBM model, TFEE in these two years are 0.338 and 1. Specifically, factor inputs fell by 3.5% and output rose by 21%, thus resulting in a sharp increase in TFEE in 2013.

5. Target for Energy Efficiency and Emission Reduction

In addition to measuring the TFEE of SBM in paper industries of EU countries, we also calculate the energy saving potential and the greenhouse gas emission reduction potential under the SBM model, providing theoretical possibility in 2030 target for energy efficiency and emission reduction and a reference point for policy makers.

5.1. Target for Energy Efficiency

The EU has committed itself to a 32.5% improvement in energy efficiency from 2021 to 2030. This objective is also known as the 32.5% energy saving target, which translates into an annual energy savings of at least 3.85%. In the case of economic growth, energy saving should first cope with increased energy consumption. Assuming that the average economic growth rate from 2021 to 2030 is the same as that from 2010 to 2019, at 2.33%, paper industries need to save at least 6.18% (3.85% + 2.33%) of energy consumption per year.

As can be seen from Table A3, the energy saving potential of each country varies greatly. Finland, Sweden, and Germany have the largest energy saving potential, with an average of 34,724 Gwh of electricity. This is not only related to the size of the paper industries and its huge energy consumption, but is also related to its energy efficiency. Ireland, Latvia, Lithuania and Slovakia have the highest energy efficiency, resulting in no potential for energy saving. Although they are all small countries, it can be seen from the input-output table that they have a good ratio among the inputs of various factors. From 2008 to 2016, the annual total energy saving potential of the paper industries in the EU showed a downward trend. While the total energy consumption remained basically unchanged, the decline of energy saving potential reflected the rise of energy efficiency. The absolute value of energy saving potential has declined, but it still accounts for a large share of total energy consumption, from more than 50% in 2008 to more than one-third thereafter, which is well above the 6.18% energy saving target. In order to achieve the 2030 energy target, the EU paper industry needs to save at least 6.18% of energy consumption annually. However, if all countries' paper industries can achieve their best in energy efficiency, 33% energy could be saved annually.

5.2. Target for Emission Reduction

EU has set a 40% target for emission cuts by 2030, which translates into an annual emission reduction of 1.37%. In the case of economic growth, EU should first cope with the increased energy consumption that is generated by economic growth in order to achieve the emission reduction target. Assuming that the average economic growth rate from 2021 to 2030 is the same as from 2010 to 2019, at 2.33%, paper industries need to reduce emissions by at least 3.7% (1.37% + 2.33%) per annum to ensure that the EU as a whole meets its 2030 target.

Table A4 shows the greenhouse gas emission reduction potential of paper industries in each country. Except for Ireland, Latvia, Lithuania and Slovakia, which have zero emission reduction potential, the greenhouse gas emission reduction potential of other countries is quite large. The overall emission potential has declined, and the emission reduction rate has dropped from 96.9% to 70.9%, which is also well above the 3.7% reduction target for 2030. The average emission reduction potential is 71%. In addition, the greenhouse gas emission reduction potential of most countries accounts for more than 90% of the actual emissions for the year, which indicates that the environmental problems can be greatly resolved by improving energy efficiency and reducing fossil energy use while maintaining the original output.

5.3. Discussion

According to TFEE of paper industries measured in this paper, the 22 EU countries are divided into three groups: high-value group, low-value group and medium-value group. The average annual energy saving potential and average annual emission reduction of each country from 2008 to 2016 are shown in Figure 2. Countries in the high-value group are countries with TFEE of 1, including Ireland, Latvia, Lithuania and Slovakia. These four countries are always at the frontier, with no potential for energy saving and emission reduction, and they are the targets for other countries to follow. Countries with lower energy efficiency than average are classified to be in the low-value group, which includes Hungary, Germany, Sweden, the Czech Republic, Belgium, Estonia, Austria, Finland and Slovenia. The average energy efficiency of these countries is 46.6%, indicating a 53.4% energy saving potential. That is equivalent to 125,473 Gwh of power savings. It is worth noting that Germany has a large paper industry with all inputs ranking first (except energy), but its TFEE is 53.9%, with 46.1% of energy saving potential, accounting for 21.5% of the total energy saving potential of EU paper industries. Finland and Sweden are the main pulping and papermaking countries in Northern Europe. Their energy inputs rank first and third in the paper industries respectively. Due to the large energy input base and large energy saving potential, which are 60.7% and 46.4% respectively, the improvement of energy efficiency of the paper industries in Finland and Sweden is of great significance to energy saving for the EU paper industry, accounting for 50% of the total energy saving potential. In addition, as Finland's paper industry is known for its high energy consumption and heavy pollution, accounting for 57% of manufacturing industry's energy consumption in 2016, its energy efficiency improvement also plays a key role in this country's energy saving targets. Finland and Sweden account for 17.1% of the greenhouse gas emission reduction potential of EU paper industries, so the improvement of energy efficiency in these two countries could also improve the environment. Moreover, Finland and Sweden, despite their high energy consumption, are relatively efficient in reducing emissions. The third group is the medium-value, with TFEE ranging from average to 1, and it includes Romania, Denmark, Greece, the United Kingdom, Portugal, Poland, Netherlands, Bulgaria and Italy. The average TFEE is 80.7%, with an energy saving potential of 19.3%. Specifically, it saves 20,129 Gwh of electricity and 11,485,532 tons of greenhouse gas emissions per year on average. As for the percentage, the medium-value group saved 13.8% of its potential energy savings, but 41.4% of greenhouse gas emissions, suggesting that the paper industries in the low-value group did better in reducing emissions than the medium-value group. UK paper industries investment was relatively large and energy efficiency was high, reaching 84.9%.

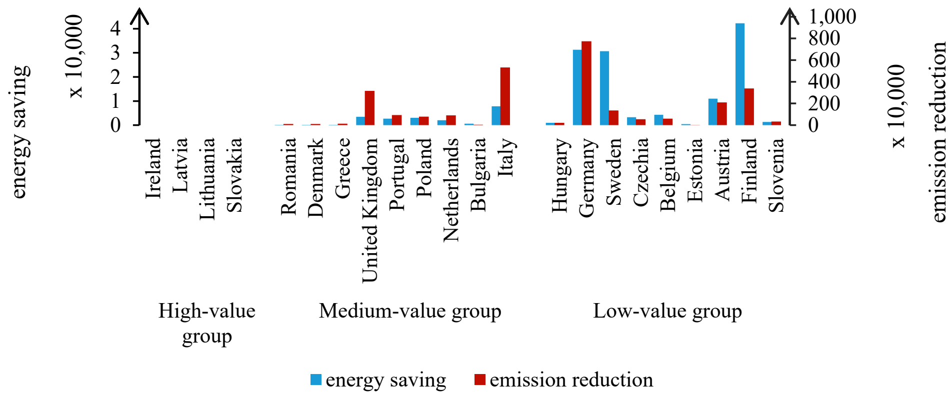

Figure 2. High-value, medium-value and low-value group of TFEE.

The overall energy price (inclusive of non-recoverable taxes) is closely related to energy efficiency. High energy price countries such as the UK (0.165 Euro/Kwh), Ireland (0.133 Euro/Kwh), Italy (0.150 Euro/Kwh) and Slovakia (0.132 Euro/Kwh) have relatively high energy efficiency, while Finland (0.070 Euro/Kwh), Sweden (0.065 Euro/Kwh) have low energy prices, more energy inputs, higher energy intensity (E/VA) and lower TFEE values. However, it is worth noting that Germany is an exception with the highest energy price (0.178 Euro/Kwh) but low energy efficiency, which needs a further investigation. Generally speaking, low energy price is closely related to low energy efficiency. Another important finding is that the countries with large scale paper industries have greater potential for energy saving and emission reduction. Due to high forest coverage rate and rich timber resources, Finland and Sweden have sufficient raw materials and therefore large scale paper industries. They can save as many as 72,890 Gwh of energy and reduce 4,742,101 tonnes emissions annually. In addition, other large scale paper industries countries like Germany (energy saving: 31,281 Gwh, emission reduction: 7,734,054 tonnes), United Kingdom (emission reduction: 3,155,538 tonnes) and Italy (emission reduction: 5,323,883 tonnes) also have large potential for energy saving and emission reduction. Overall, these five countries can save 115,487 Gwh of energy and reduce 20,955,576 tonnes of emissions per year if their TFEE value could reach 1, accounting for 79% of energy savings and 75% of total emissions reductions in the EU paper industry.

It is believed that EU policy makers should raise energy consumption cost (prices or non-recoverable taxes), thereby encouraging energy-intensive countries to actively seek ways to improve energy efficiency or increase the share of renewable energy. As for energy saving, the EU should focus more on major paper producing countries, such as Finland, Sweden, and Germany. As for emission reduction the EU should focus more on countries like Germany, United Kingdom, Italy and Finland. These five countries have a greater potential for energy saving and emission reduction, which is critical to achieve the EU's 2030 targets.

6. Conclusions

Improving energy efficiency has become the key solution for economic development, energy saving and environmental problems at the same time. Therefore, this paper aims to measure the energy efficiency of paper industries in EU countries, estimate potential energy saving and emission reduction, and make a comparison with the 2030 targets. The following are the conclusions: (1) SBM and CCR efficiency value is more meaningful for policy makers than that of energy intensity, as measurement results of energy intensity deviate from reality and economic efficiency. (2) By applying a complete set of input and output indicators, we estimate that average TFEE for EU paper industry under SBM is 0.71, and countries like Ireland, Latvia, Lithuania and Slovakia are examples that should be followed by others, for they are always at the frontier of efficiency. (3) When paper industries in every EU country make efficient use of energy by referring to countries on the frontier, they have an energy saving potential (of at least 33%) and emission reduction potential (of at least 71%) annually, which is well above the EU 2021–2030 target of 6.18% and 3.17%.

Furthermore, the 22 EU countries are divided into high-value, medium-value and low-value groups according to the energy efficiency level, and another important finding is that among them, the low-value group has the greatest energy saving potential, especially for countries like Finland, Sweden and Germany, which EU and relevant governments should focus more on to improve energy efficiency in those countries. At the same time, countries in the medium-value group like Italy and United Kingdom still need to make efforts to reduce greenhouse gas emissions.

For individual countries, it is suggested that EU policy makers should raise energy consumption cost by increasing energy prices or non-recoverable taxes, encourage energy-intensive countries to actively seek ways to improve energy efficiency and increase the usage of renewable energy. As for energy saving and emission reduction, the EU should focus more on major paper producing countries, such as Finland, Sweden, Germany, United Kingdom, and Italy, which have greater potentials in energy saving and emission reduction. This is critical for the EU to achieve the 2030 targets.

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Appendix A

Table A1. Descriptive statistics of inputs.

Country	Inputs							
	Capital (Million Euro)		Labor (Million Euro)		Energy Consumption (Gigawatt-Hour)		Other Intermediate Consumption (Million Euro)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Belgium	5686	588	1388	158	8340	332	4374	373
Bulgaria	527	53	82	12	2355	630	343	54
Czechia	2565	76	539	47	6901	144	2130	222
Denmark	1789	263	654	121	1226	375	1536	169
Germany	30,214	3065	12,150	561	68,436	2478	32,709	2605
Estonia	201	9	59	5	700	58	217	14
Ireland	986	113	385	61	291	12	1024	313
Greece	1047	110	411	87	1163	309	1241	92
Italy	18,327	2214	5249	383	27,091	1778	20,314	1341
Latvia	210	5	40	6	86	25	187	24
Lithuania	201	56	73	15	402	105	230	66
Hungary	1337	133	293	35	2041	268	1248	124
Netherlands	6339	1028	2090	199	7808	1002	6863	355
Austria	5050	501	1607	75	19,016	626	4169	394
Poland	5782	562	1069	119	16,155	2178	5638	968
Portugal	3495	298	548	80	15,277	761	1884	232
Romania	1101	180	204	49	1248	369	923	161
Slovenia	790	84	184	19	2026	130	615	43
Slovakia	1359	348	182	7	5821	789	512	171
Finland	9485	1577	1828	255	69,534	4138	6335	622
Sweden	11,118	808	2737	257	66,102	7897	6488	733
United Kingdom	13,431	1261	5712	602	22,182	2123	14,559	1450

Table A2. Descriptive statistics of outputs.

Country	Outputs					
	Gross Output (Million Euro)		Waste Residue (Tonne)		Greenhouse Gas (Tonne)	
	Mean	SD	Mean	SD	Mean	SD
Belgium	7197	479	946,510	348,782	600,867	65,898
Bulgaria	725	88	86,701	41,826	176,075	45,886
Czechia	3900	310	319,678	16,896	555,491	75,419
Denmark	2515	341	131,382	32,063	115,566	21,011
Germany	56,442	3728	3,554,700	310,871	7,734,987	730,705
Estonia	373	24	109,967	12,476	71,021	5543
Ireland	1607	346	145,829	116,137	18,027	3174
Greece	1998	333	116,700	36,265	157,264	50,068
Italy	32,851	2198	1,903,056	131,816	5,324,694	324,764
Latvia	283	26	7614	3772	124,995	17,399
Lithuania	502	106	50,620	11,409	45,381	14,807
Hungary	1977	148	207,565	52,180	228,923	90,738

Table A2. *Cont.*

Country	Outputs					
	Gross Output (Million Euro)		Waste Residue (Tonne)		Greenhouse Gas (Tonne)	
	Mean	SD	Mean	SD	Mean	SD
Netherlands	10,853	835	698,117	92,351	908,386	145,953
Austria	8471	570	630,331	129,295	2,098,280	251,005
Poland	10,051	1403	1,607,329	303,672	2,140,395	403,714
Portugal	4620	234	607,310	125,965	1,490,102	193,030
Romania	1752	343	157,753	44,652	339,321	64,726
Slovenia	1093	43	180,759	9384	357,592	42,704
Slovakia	1678	55	338,399	118,181	173,895	14,960
Finland	14,004	1335	4,388,784	614,598	3,392,642	392,998
Sweden	15,504	1149	2,870,469	1,906,449	1,357,841	348,653
United Kingdom	27,399	2197	1,762,397	271,372	3,880,237	584,932

Table A3. Energy saving potential.

	Year									
Countries	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average
Belgium	5132	1962	3935	4325	5122	5374	6348	3355	3264	4313
Bulgaria	1620	431	1240	0	0	0	316	1006	630	582
Czechia	4785	2738	3145	3815	4821	4641	1944	2194	1564	3294
Denmark	0	132	57	45	140	187	239	319	61	131
Germany	33,615	18,211	10,932	22,357	36,769	40,495	45,158	44,483	29,509	31,281
Estonia	392	362	311	435	489	0	544	554	529	402
Ireland	0	0	0	0	0	0	0	0	0	0
Greece	0	0	0	0	352	410	374	221	0	151
Italy	10,168	1496	0	793	12,179	10,906	13,569	14,081	7370	7840
Latvia	0	0	0	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0	0	0	0
Hungary	671	634	0	350	1332	1460	1781	1176	1167	952
Netherlands	3277	2309	0	290	2919	3950	2835	2516	434	2059
Austria	12,736	6019	9699	11,531	12,776	13,927	14,877	9492	7906	10,996
Poland	9018	6550	3507	8514	0	0	0	0	0	3066
Portugal	7208	4351	2493	4902	4262	1277	0	0	0	2722
Romania	0	0	0	0	0	0	77	854	0	104
Slovenia	1606	763	1234	1313	1454	1374	1529	1327	1510	1346
Slovakia	0	0	0	0	0	0	0	0	0	0
Finland	53,564	41,444	42,858	44,181	43,904	33,040	41,791	38,851	40,283	42,213
Sweden	40,170	39,931	33,244	30,126	32,727	15,354	21,588	31,215	31,736	30,677
United Kingdom	8398	0	0	3089	6109	6140	7549	0	0	3476
	8744	5788	5121	6185	7516	6297	7296	6893	5726	
Average	201,102	133,121	117,776	142,249	172,871	144,832	167,817	158,536	131,687	
Sum	0.552	0.394	0.329	0.411	0.506	0.421	0.523	0.464	0.383	
saving rate	0	0	0	0	0	0	0	0	0	0

Notes: (1) “saving rate” means the ratio between the energy saving potential of paper industries and actual energy consumption. (2) Significant changes in energy saving potential are due to changes in TFEE on the one hand and their own energy consumption on the other.

Table A4. Emission reduction potential.

Countries	Year									Average
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Belgium	551,453	509,644	665,357	554,526	555,480	545,426	633,864	674,205	672,698	595,850
Bulgaria	62,751	85,317	9993	0	0	0	0	31,401	136,226	36,188
Czechia	643,500	632,677	605,320	575,569	586,300	488,974	459,458	452,531	443,552	543,098
Denmark	131,575	117,043	127,569	119,085	100,087	90,382	91,805	89,508	59,304	102,929
Germany	8,909,735	8,150,159	8,278,544	7,502,447	7,271,315	7,810,048	7,709,144	7,710,071	6,265,023	7,734,054
Estonia	33,861	0	0	1838	0	0	3811	6652	0	5129
Ireland	0	0	0	0	0	0	0	0	0	0
Greece	238,624	173,677	172,564	144,930	108,045	124,808	126,342	100,770	0	132,196
Italy	5,329,307	4,869,408	5,828,271	5,536,462	5,433,395	5,346,983	5,051,982	5,607,798	4,911,341	5,323,883
Latvia	0	0	0	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0	0	0	0
Hungary	206,252	153,394	180,808	179,502	169,091	201,993	210,233	157,921	438,029	210,803
Netherlands	1,080,318	949,514	1,070,135	989,110	959,880	870,804	862,835	680,459	682,150	905,023
Austria	2,260,183	2,289,374	2,411,293	2,358,013	2,117,563	2,004,328	1,784,869	1,884,098	1,744,927	2,094,961
Poland	1,460,180	1,561,680	1,894,079	2,181,127	0	0	0	0	0	788,563
Portugal	1,106,543	1,242,107	1,509,692	1,568,846	1,525,400	1,440,209	0	0	0	932,533
Romania	0	0	0	0	0	0	283,111	348,781	346,234	108,681
Slovenia	411,494	391,248	360,445	328,749	312,511	303,251	304,219	288,652	283,029	331,511
Slovakia	0	0	0	0	0	0	0	0	0	0
Finland	4,119,281	3,415,914	3,886,194	3,561,349	3,193,726	3,173,177	3,084,347	3,047,750	3,014,464	3,388,467
Sweden	1,918,604	1,607,251	1,678,737	1,504,578	1,386,596	1,161,576	1,002,398	935,178	987,786	1,353,634
United Kingdom	5,138,013	4,383,832	3,932,540	3,802,451	3,802,514	3,737,316	3,603,171	0	0	3,155,538
Average	1,527,349	1,387,829	1,482,343	1,404,936	1,250,996	1,240,876	1,145,981	1,000,717	908,398	
Sum	33,601,673	30,532,240	32,611,540	30,908,582	27,521,904	27,299,276	25,211,590	22,015,775	19,984,762	
Reducing rate	0.969	0.972	0.965	0.969	0.894	0.885	0.843	0.729	0.709	

Notes: "Reducing rate" means the ratio between the potential reduction of greenhouse gas emissions and actual emissions.

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