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The Importance of Higher Education in the EU Countries in Achieving the Objectives of the Circular Economy in the Energy Sector

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Abstract: The main purpose of the article was to identify and present the current situation and changes in higher education in the field of electricity and energy studies in the European Union countries. The specific objectives include determining the degree of concentration of education in the fields of electricity and energy in the EU countries, showing the directions of their changes, types of dominant education in this field, establishing the correlation between education in the fields of electricity and energy and the parameters assessing the achievement of circular economy assumptions in the energy sector. All Member States of the European Union were deliberately selected for research. The research period covered the years 2013–2018. The source of the materials is a literature review on the subject and Eurostat data. For the analysis and presentation of materials, methods such as descriptive, tabular, graphical, dynamics indicators with a constant basis, Gini concentration coefficient, concentration analysis using the Lorenz curve, coefficient of variation, Pearson's linear correlation coefficient were used. A high concentration of education in the fields of electricity and energy was found in several EU countries, the largest in countries with the highest energy consumption, i.e., in France and Poland. Changes in the level of concentration practically did not take place, only in the case of master's studies, there was an increase in concentration. However, the EU countries did not differ significantly in terms of the structure of the number of students studying electricity and energy.

Keywords: higher education; energy; circular economy

1. Introduction

Circular economy (CE) is a concept aiming to rationalize the use of resources and reducing the negative environmental impact of manufactured products. Materials, raw materials, and products should remain in the economy as long as possible, and the generation of waste should be minimized as much as possible [1–9]. The concept of a circular economy was first used in 1981 by Wathler Stahel and Genevieve Redayw. In their work entitled "Jobs for Tomorrow, the Potential for Substituting Manpower for Energy" they presented a model of what they called looped or circular economy. They also described the influence of such model on a rational approach to production, employment, price competitiveness, and above all, to saving resources and preventing the formation of post-production waste. The waste input–output model has been extended to wide areas of industrial ecology including material flow analysis, life-cycle costing, regional analysis, and linear programming based technology selection. Their concept has gained extraordinary popularity in Anglo-Saxon and Scandinavian countries [10–14].

In the European Union, the first package of economic solutions in a closed system was presented in July 2014 by the President of the European Commission José Manuel Barroso. However, it was not well received by some member states and business representatives. The resistance to the circular economy proposal was caused by a large interference in the legislation of the Member States when introducing the necessary legal provisions. The plan of the European Commission included a requirement to implement in national legislation the laws on recycling or recovery of secondary raw materials from waste. On 18 December 2017, Member States reached a political agreement on new recycling targets [15–18].

Model solutions in the field of CE concern many areas of economic activity and social aspects, i.e., the economy of sharing, assessing, and promoting the durability and energy efficiency of products, increasing the role of services, repair, reuse, introducing extended producer responsibility, product life cycle assessment, economic symbiosis and, above all, increase in recycling. In the implementation of the CE concept, apart from recycling, it is important to circulate materials, raw materials, and products throughout the supply chain. This means, inter alia, restoring and repairing items, selling services instead of products, a new approach to energy and the use of fuels for energy production that improve the condition of the natural environment, e.g., by reducing the volume of waste produced [19–26].

In terms of energy policy, the circular economy is closely related to increasing energy efficiency, developing renewable energy sources and reducing greenhouse gas emissions. It is important to minimize the use of energy resources with low or decreasing availability (so-called non-renewable resources) and maximize the use of renewable energy sources [27–32].

Promoting and implementing solutions in the CE area requires investment activities, as well as organizational, legislative, and educational activities. Governments and regulators should adapt, for example, taxation to promote a circular economy in companies. Communication and information strategies are also needed to raise producers' and the public's awareness of CE [33–41]. CE requires the adoption of new business models and the classical "reduce, reuse and recycle" approach. Moreover, a friendlier context (fiscal, legal, organizational, etc.) and the more substantial support from supply chain agents and consumers are required [42].

Knowledge of the circular economy is concentrated in large industries and dispersed in small and medium-sized enterprises. It is important to introduce this knowledge into academic and vocational training. Then, actions for CE will be taken from the bottom up in small and medium-sized enterprises employing graduates with economic and technical knowledge enabling them to change business models, towards CE. In addition, scientists should look for innovations that will better achieve the goals of CE. Therefore, advanced scientific research is necessary [43–47].

2. Aim and Methods

The main purpose of the paper was to identify and present the current situation and changes in higher education in the field of electricity and energy education in the European Union countries. The specific objectives include determining the degree of concentration of education in the fields of electricity and energy in the EU countries, showing the directions of their changes, types of dominant education in this field, establishing the correlation between education in the fields of electricity and energy and the parameters assessing the achievement of circular economy assumptions in the energy sector. Two hypotheses were put forward in the study. According to the first, there was a diversification of education in the fields of electricity and energy in the EU, with a systematic increase in the importance of education in this field in developing countries. The second hypothesis assumed that the increase in the number of students studying electricity and energy corresponded to better results of the parameters assessing the achievement of the objectives of the circular economy in the energy sector, and that the quality of education is also of great importance. All Member States of the European Union were deliberately selected for research as of 31 December 2018 (28 countries). The research period covered the years 2013–2018. The research period was chosen on purpose. The year 2013 precedes the interest in the idea of CE in the EU. The first package of economic solutions in a closed system was presented in July 2014. It was possible to notice the state of education immediately before and in the later years after the beginning of the interest in the idea of CE. The year 2018 was the last year for which data was available at the time of writing this article. The sources of materials were the literature on the subject, data from Eurostat. Descriptive, tabular, and graphical methods were used for the analysis and presentation of materials, as well as dynamics indicators with a constant basis, Gini concentration coefficient, concentration analysis using the Lorenz curve, coefficient of variation, Pearson's linear correlation coefficient.

In the first stage of the research, the number of students studying electricity and energy was presented. This direction was chosen on purpose. The Eurostat database is divided into groups of education courses. Of course, in various fields of study, knowledge may be passed on individual subjects related to energy (e.g., renewable energy), but it is not a complete education in this field. For example, a research mapping higher education for sustainable development in Portugal concluded that Education for Sustainable Development (ESD) is covered in most Social Sciences, Engineering, and Management, BSc and MSc courses offered by the top eight Portuguese Higher Education Institutions. However, ESD is fragmented by different approaches, issues, methodologies, and implications, lacking a consistent body of knowledge [48]. In the group of electricity and energy faculties, students pursue many subjects related to renewable energy and learn about the idea of CE. Therefore, these types of students can have a greater impact on achieving the CE assumptions in the energy sector. Research data refer to the number of students at the end of the year on December 31 of the given year.

In the second stage, the Gini concentration coefficient was calculated. It concerned the number of students studying electricity and energy in the European Union countries. The Gini coefficient was used to determine the degree of concentration of education. It was measured based on the number of students studying electricity and energy in EU countries. If such education were provided in one country, the coefficient would be 1. If it was spread over more countries, the coefficient had lower values, the closer it was to 0, the more it proves that the number of students is evenly distributed among the EU countries. The Lorenz curve is a graphical representation of the degree of student concentration in the EU countries.

The Gini coefficient is a measure of unevenness (concentration) of distribution of a random variable. When the observations y_i are sorted in ascending order, the coefficient can be represented by the formula [49]:

$$G(y) = \frac{\sum_{i=1}^{n} (2i - n - 1) \times y_i}{n^2 \times \overline{y}} \quad (1)$$

where: n—number of observations, y_i—value of the "ith" observation, $\overline{y}$—the average value of all observations, i.e., $\overline{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$.

The Lorenz curve determines the degree of concentration of a one-dimensional random variable distribution [50]. With sorted observations y_i, which are non-negative values $0 \leq y_1 \leq y_2 \leq \ldots \leq y_n$, $\sum_{i=1}^{n} y_i > 0$, the Lorenz curve is a polyline which apexes (x_h, z_h), for $h = 0,1, \ldots ,n$, have the following coordinates:

$$x_0 = z_0 = 0,\ x_h = \frac{h}{n},\ z_h = \frac{\sum_{i=1}^{h} y_i}{\sum_{i=1}^{n} y_i} \quad (2)$$

The Gini coefficient determines the area between the Lorenz curve and the diagonal of a unit square multiplied by 2.

The third stage of the research presents the structure of the number of students in the fields of electricity and energy. The participation of students was shown on the three levels of education: Bachelor, Master, and PhD. Such division functions in all EU countries. Only four countries were selected for analysis. Two belonged to economically developed countries (Spain and the Netherlands), and two to developing countries (Poland and the Czech Republic). Among the countries, some countries recorded an increase in the number of students studying electricity and energy (NL) as well as a decrease (PL, CZ, ES). These were countries with different numbers of students studying in the fields of electricity and energy. In the EU they were ranked 2nd, 4th, 10th, and 20th, respectively, according to this criterion. The four countries were diverse in many aspects.

In the fourth stage, indicators of the dynamics of the number of students for the levels of studies in the field of electricity and energy studies were calculated. As a result, information was obtained on the directions and strength of changes in education in the fields of electricity and energy.

The dynamics indicators with a fixed base are determined as follows [51]:

$$i = \frac{y_n}{y_0} \text{ or } i = \frac{y_n}{y_0} \cdot 100\% \tag{3}$$

where: y_n—the level of the phenomenon in a certain period, y_0—the level of the phenomenon during the reference period.

In the fifth stage, the coefficients of variation for the number of students studying electricity and energy for the years 2013–2018 were calculated. Thanks to this, it was possible to determine whether the situation was stable or whether the number of students was very variable.

The coefficient of variation denoted *Cv* eliminates the unit of measurement from the standard deviation of a series of numbers by dividing it by the mean of this series of numbers. Formally, for a series of N numbers, the coefficient of variation is computed as [52]:

$$C_v = \frac{S}{M} \tag{4}$$

where: *S*—standard deviation from the sample, *M*—arithmetic mean from the sample.

In the sixth stage, the relationship between the number of students studying electricity and energy in the EU countries and the parameters assessing the achievement of circular economy assumptions in the energy sector was examined. The parameters were selected on purpose based on the literature review. In the energy sector in CE, energy efficiency is important. It can also be increased by introducing machines and devices that consume less energy. In the article, the authors used the available indicators in this area, such as electricity consumption per person, or its total consumption. Another aspect of CE in the energy sector is the reduction of greenhouse gas emissions. Therefore, these emissions have been taken into account in energy consumption. The last aspect concerns the consumption of energy derived from renewable resources. Preferably such sources are in line with CE assumptions. The research involved parameters related to the share of renewable energy in energy consumption in relation to individual sectors and as a whole. The presented parameters draw attention to all the most important aspects related to CE in the energy sector.

Pearson's linear correlation coefficient is a measure of the strength of a straight-line relationship between two measurable features. It is expressed through the following formula [53]:

$$r_{XY} = \frac{C(X,Y)}{\sqrt{{S_X}^2 \cdot {S_Y}^2}} = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2 \cdot \sum_{i=1}^{n}(y_i - \overline{y})^2}} = \frac{C(X,Y)}{S_X \cdot S_Y} \tag{5}$$

where: *C(X,Y)*—covariance between the *X* and *Y* features, ${S_X}^2$—*X* feature variance, ${S_Y}^2$—*Y* feature variance, S_X—*X* feature's standard deviation, S_Y—*Y* feature's standard deviation.

The linear correlation coefficient can be considered as normalized covariance. Correlation always takes values in the range (−1, 1).

3. Results and Discussion

In the years 2013–2018, the number of students studying electricity and energy decreased by 15%. Students enrolled in these fields accounted for around 1% of enrolled students in the EU. In Finland, it was even 3.5% in 2018, in Romania 2.6%, in Latvia 2.2%, and in Bulgaria 2%. There were also countries that did not offer studies in these fields. There were three levels of education: bachelor, master, and doctorate (Figure 1). The largest decrease was recorded in the case of doctoral students (by 30%), then undergraduate (by 25%), and the lowest for graduate students (by 3%).

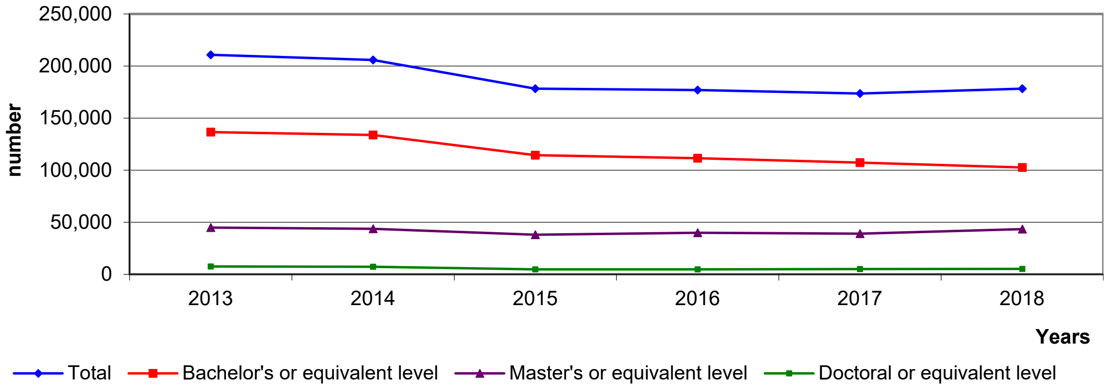

Figure 1. Number of students studying electricity and energy in 2013–2018.

The Gini coefficient was used to determine the degree of concentration of education in the fields of electricity and energy in the EU countries [54]. This coefficient is a correct and commonly used measure of inequality because it meets all the axioms postulated in this respect. Its values range from 0 to 1. A result close to 1 means that there is a very high concentration of education in the fields of electricity and energy in one country, and close to 0 indicates the dispersion of education among many countries. The number of observations was 28 (all EU countries). The results are presented for general education in the fields of electricity and energy and for its three levels, i.e., bachelor, master, doctor. The Gini coefficient for total education in the fields of electricity and energy in 2013, calculated from the sample, was 0.66, and the estimated coefficient for the population was 0.69. This meant a fairly high concentration of education in the fields of electricity and energy in several EU countries. In the case of repeating the research for 2018, the results were virtually identical. Therefore, there have been no significant changes in the distribution of education in the fields of electricity and energy in the EU countries. The Gini coefficients for education in the fields of electricity and energy were also calculated for each level of education. Additionally, the differentiation was presented using the Lorenz concentration curve (Figure 2) [55]. In 2018, the level of concentration of education in the fields of electricity and energy was the highest in the case of doctoral studies (the coefficient from the sample was 0.70, and the estimated 0.73), and the lowest for master's studies (from the sample 0.63, estimated 0.66). In 2018, 19% of all students studying electricity and energy in the EU countries studied in France, 16% in Poland, and 13% in Germany. In the case of undergraduate studies, Poland had 16% of students, Germany and France 13% each. For master's degrees, it was, respectively, 20% in France, 13% in Italy, and 12% in Germany. The largest number of students enrolled in doctoral studies in the EU was in Finland (20%), Spain (14%), and Romania (13%). Overall, there were very few differences between study levels in the concentration of education. Concentration ratios were also calculated for the earlier period, i.e., 2013. Such a combination allows to determine the direction and pace of changes in the concentration of education in the fields of electricity and energy. In general, it can be noticed that the level of concentration of education is maintained in several countries (Table 1). There has been an increase in the concentration of education in the case of graduate studies, and little for doctoral studies, and there has been no change for the undergraduate studies. Maintaining the concentration level of education can be confusing, however, as changes and shifts may have occurred between individual countries.

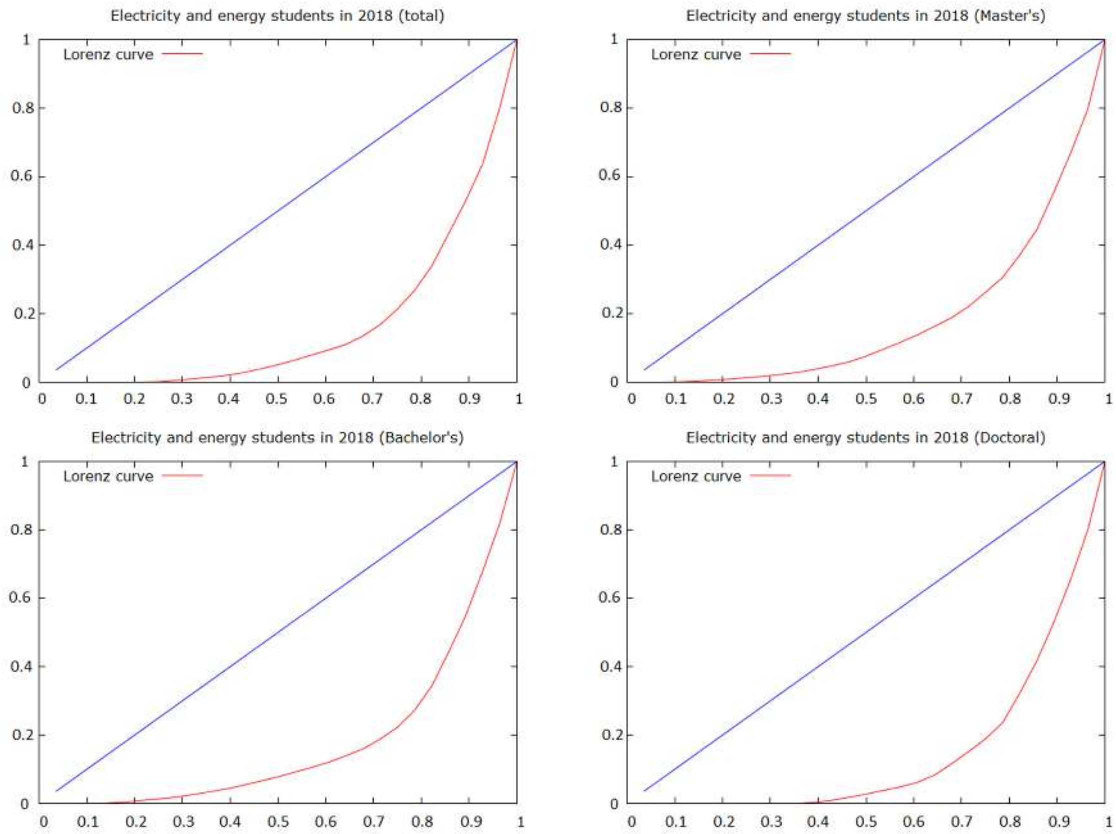

Figure 2. Lorenz concentration curves for electricity and energy education in the EU countries in 2018.

Table 1. Gini coefficients for education levels in the fields of electricity and energy in the EU countries in 2013–2018.

Educational Levels	Gini Coefficients in Years			
	2013		2018	
	From Sample	Estimated	From Sample	Estimated
Total	0.66	0.69	0.68	0.70
Bachelor's	0.65	0.67	0.64	0.67
Master's	0.58	0.60	0.63	0.66
Doctoral	0.69	0.71	0.70	0.73

Changes between countries in the field of education in electricity and energy majors varied, with the highest increases in the number of students in France (63%) and Denmark (40%), and the greatest decrease in the Czech Republic (by 80%), Slovakia (by 66%), and in Romania (by 48%). For undergraduate programs, the largest increases in student numbers were recorded in Ireland (105%) and Denmark (74%), and the largest decreases in the Czech Republic (83%) and Slovakia (70%). For master's degrees, the largest increases in the number of students were in Denmark (148%) and France (103%), and the decrease in the Czech Republic (72%) and Slovenia (68%). In the case of doctoral studies, the largest number of students increased in Spain (by 399%) and Belgium (by 24%), and the decrease in the Czech Republic (by 82%) and Slovakia (71%). There were also countries where electricity and energy education was not offered, or where only a few levels of study were allowed, for example without doctoral studies. Each country has a separate history and conditions, also in the field of electricity and energy education. Four different countries, i.e., Poland, Spain, the Netherlands, and the Czech Republic, were selected for a more detailed analysis. Poland has the second largest number of students studying electricity and energy consumption among all EU countries. It was a developing country that joined the EU in 2004, which based its energy on fossil fuels. The total number of students studying electricity and energy decreased by 10% in the analyzed period. In turn, Spain was economically developed and had a large population. In 2013–2018, the number of students studying electricity and energy fell in this country by 29%. Despite this, Spain was fourth in terms of the number of students in the EU. The Netherlands was also an economically developed country. In this country, the number of students increased by 19%, placing it in 10th place. The Czech Republic was one of the countries admitted to the EU in 2004 (like Poland), making up for their backwardness in relation to European countries. The country ranks 20th in the EU in terms of the number of students studying electricity and energy.

In Poland, more than $\frac{3}{4}$ of students studying electricity and energy studied at bachelor's degree, only 18–20% at master's studies, and only 2% at doctoral studies (Figure 3). The share of undergraduate students declined in favor of graduate studies, and the share of doctoral students remained unchanged. In the case of Spain, undergraduate students also dominated, but its share increased from 78% in 2013 to 81% in 2018 (Figure 4). On the other hand, the share of master's students decreased from 21% to 13%, and the share of doctoral studies increased from 1% to 6%.

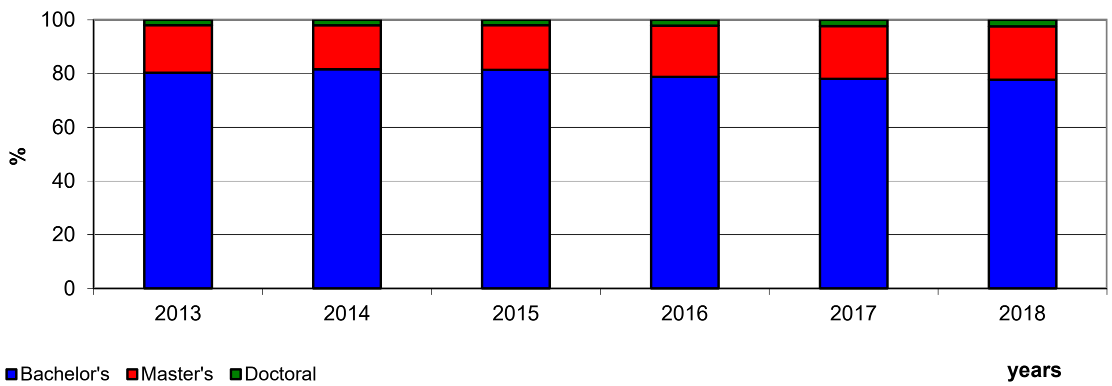

Figure 3. Structure of education in the fields of electricity and energy in Poland in 2013–2018.

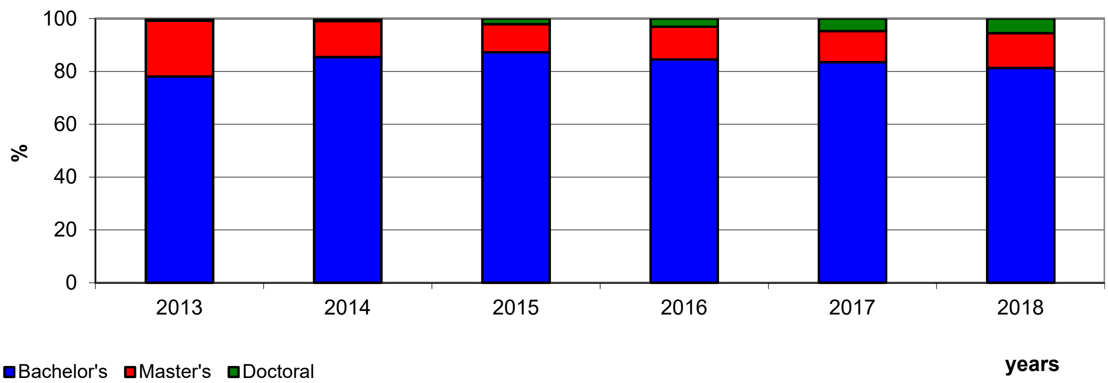

Figure 4. Structure of education in the fields of electricity and energy in Spain in 2013–2018.

In the Netherlands, the share of undergraduate students in electricity and energy studies was at a similar level to that in Spain (Figure 5). In this country, however, the importance of this level of studies decreased, as the share fell from 82% in 2013 to 78% in 2018. The remaining share fell on master's studies. In the Netherlands, no students enrolled in doctoral studies in the studied field were recorded. In the Czech Republic, there have been very large changes in the structure of students studying electricity and energy (Figure 6). The reason was the large reduction in the number of students. Bachelor's studies lost their importance (decrease from 63% to 54% in 2013–2018), while master's studies gained in importance (increase from 23% to 33%). A positive aspect was the high share of students in doctoral studies, which amounted to over a dozen percent throughout the entire period under study.

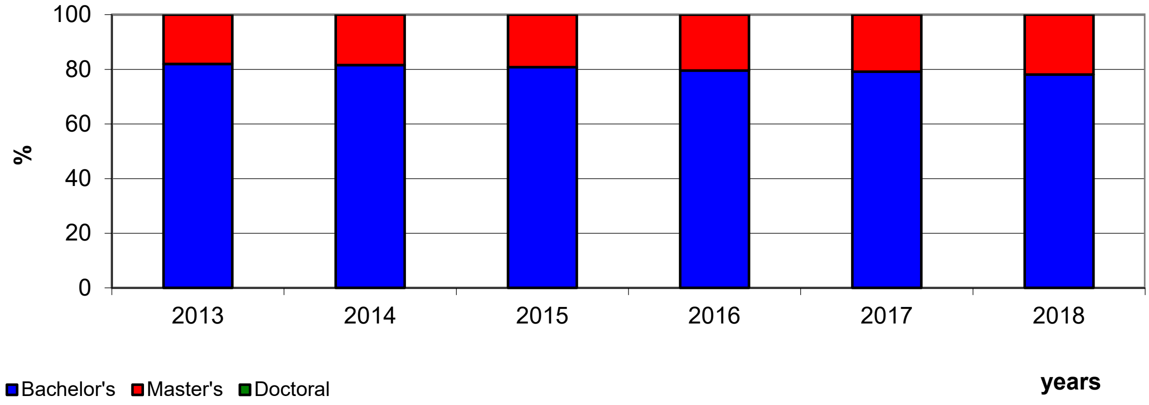

Figure 5. Structure of education in the fields of electricity and energy in the Netherlands in 2013–2018.

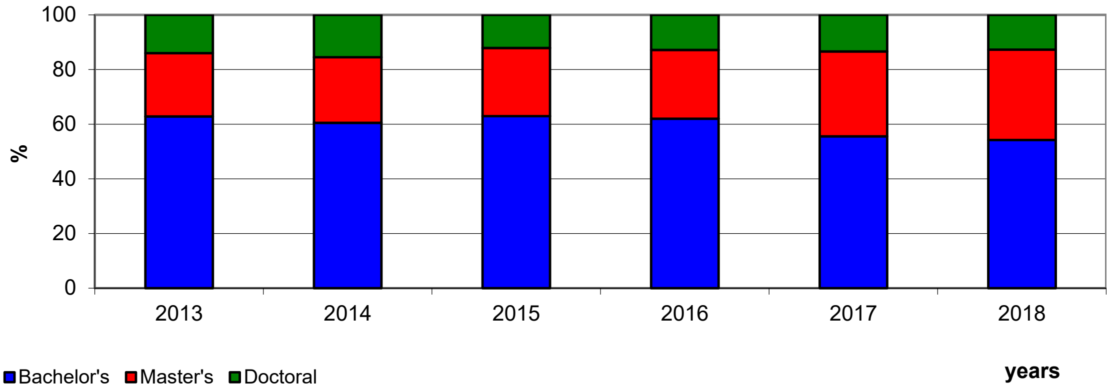

Figure 6. Structure of education in the fields of electricity and energy in Czechia in 2013–2018.

In the EU countries, undergraduate studies were of the greatest importance. In 2013, 72% of students studying electricity and energy studied at this level, and 69% in 2018. The next places were taken by master's studies (an increase from 24% to 29% in 2013–2018) and doctoral studies (a decrease from 4% to 3%). Such a structure of students shows that in many countries people obtain the first level of higher education, a smaller proportion decide to continue their studies in a given field of study at master's studies. A very small percentage pursue doctoral studies. It is also connected with the level of difficulty of studying at a given level and with the ambitions and needs of people, often with taking up a job and focusing on it or starting a family, devoting time to it. There are many similarities between countries, but also differences, especially at higher levels of education. The number of students also changed quite dynamically.

In the next stage, the indicators of the dynamics of the number of students for the levels of studies in the field of electricity and energy were calculated. The level from 2013 was used as the basis (Table 2). Within 5 years, the increase in the number of students was recorded in six EU countries, by far the largest in France, but also significant in Denmark, Italy, and the Netherlands. On the other hand, very large drops occurred in the Czech Republic, but also significant in Slovakia, Romania, Estonia, Lithuania, and Greece. The reason for the declines may be market saturation with specialists in the field of electricity and energy. Changes in the number of students may also result from policies pursued at the country level or at the Higher Education Institutes (HEIs). Each country should be analyzed separately due to the existing economic and social conditions. The number of students at bachelor's level has increased in eight EU countries, at master's level in seven countries, and at doctorate level in four countries. There were also countries that did not show education in electricity and energy in 2013. Therefore, it was not possible to calculate the dynamics index for such countries.

Table 2. Dynamics indicators for the number of students studying electricity and energy in EU countries in 2013–2018 (year 2013 = 100).

Countries	Dynamics Indicators for Education Levels in 2013–2018			
	Total	Bachelor's	Master's	Doctoral
France	162.61	135.77	202.85	98.47
Denmark	139.73	173.84	248.24	-
Italy	135.36	-	135.43	-
Netherlands	119.15	113.50	144.86	-
Cyprus	110.52	98.74	91.12	85.19
Finland	108.20	102.08	160.93	92.94
Croatia	98.85	108.73	87.20	0.00
Sweden	98.84	104.29	115.94	102.11
Germany	98.77	87.87	154.01	-
Latvia	98.21	99.10	85.53	95.77
Austria	93.23	95.67	98.11	88.45
Malta	90.99	127.94	58.33	-
Poland	89.53	84.90	98.32	107.27
EU	84.53	75.08	96.63	69.59
Belgium	79.57	83.63	70.28	123.74
Bulgaria	73.29	73.69	71.83	74.83
Spain	71.04	74.12	44.49	499.34
Hungary	68.28	69.52	98.73	100.00
Ireland	68.11	204.55	70.65	-
Portugal	67.86	52.47	75.43	84.16
Luxembourg	67.35	40.82	-	-
Slovenia	62.39	76.03	31.71	42.22
Greece	60.31	62.08	77.21	-
Lithuania	58.58	56.30	68.48	82.86
Estonia	53.08	47.27	67.52	74.32
Romania	51.60	59.42	35.72	44.66
Slovakia	34.04	29.72	45.08	29.35
Czechia	19.86	17.14	28.31	18.09
United Kingdom	-	-	-	-

Then, the coefficients of variation for the number of students studying electricity and energy for the years 2013–2018 were calculated (Table 3). In the case of the total number of students in most EU countries, there were no large fluctuations in the number of students in individual years. Large fluctuations occurred in the Netherlands, Italy (large increases), and Slovenia (large decreases). The number of students in master's studies was also more stable than in undergraduate studies, and the least stable in doctoral studies. Latvia, Austria, and Finland were among the most stable countries in terms of educating students in the fields of electricity and energy. These were countries quite developed in the use of renewable energy sources. Overall, there was no single common trend for all or most EU countries. It resulted from different levels of energy development, the use of renewable energy sources, innovative technologies, the development of education and traditions in the field of electricity and energy education.

Table 3. Coefficients of variation for the number of students studying electricity and energy in EU countries in 2013–2018.

Countries	Coefficients of Variation for the Number of Students by Education Level			
	Total	Bachelor's	Master's	Doctoral
Latvia	0.02	0.04	0.09	0.07
Austria	0.03	0.06	0.10	0.04
Finland	0.04	0.04	0.17	0.03
EU	0.04	0.11	0.06	0.20
Cyprus	0.09	0.10	0.12	0.16
Denmark	0.11	0.18	0.32	-
Bulgaria	0.12	0.11	0.15	0.13
Luxembourg	0.12	0.32	0.73	-
Spain	0.12	0.10	0.40	0.57
Ireland	0.13	0.32	0.18	-
Portugal	0.14	0.24	0.09	0.10
Hungary	0.14	0.13	0.03	0.08
Belgium	0.15	0.21	0.15	0.46
Lithuania	0.16	0.18	0.13	0.10
Malta	0.17	0.17	0.26	2.24
France	0.20	0.16	0.23	0.04
Estonia	0.24	0.28	0.17	0.14
Greece	0.29	0.27	0.36	1.42
Romania	0.32	0.23	0.52	0.53
Slovakia	0.47	0.63	0.28	0.48
Croatia	0.71	0.04	0.06	0.77
Poland	0.71	0.07	0.07	0.05
Czechia	0.76	0.78	0.67	0.82
Slovenia	1.01	0.11	0.42	0.33
Italy	2.24	1.12	0.10	-
Netherlands	2.24	0.04	0.13	-
Germany	-	0.06	0.14	-
Sweden	-	0.03	-	0.02
United Kingdom	-	-	-	-

In order to establish the relationship between the number of students studying electricity and energy in the EU countries and the parameters assessing the achievement of the circular economy in the energy sector, Pearson's linear correlation coefficients were calculated (Table 4). $p = 0.05$ was adopted as the border value of the significance level [56]. Significant results are marked in bold in the table. Correlation coefficients were calculated for all EU countries for the entire period 2013–2018. The study tried to check the correlation, which does not indicate that a given factor affects another, but that there is a strong or weak relationship between them. In the case of education in the fields of electricity and energy, the calculations used the total number of students in these fields of study and at individual levels, i.e., undergraduate, graduate, and doctoral studies.

Table 4. Pearson's linear correlation coefficients between the number of electricity and energy students and the parameters assessing the achievement of circular economy in the energy sector.

Tested Parameters	Pearson's Linear Correlation Coefficients							
	Total		Bachelor's		Master's		Doctoral	
	r	p-Value	r	p-Value	r	p-Value	r	p-Value
Energy productivity (Euro per kilogram of oil equivalent)	−0.052	0.503	−0.133	0.086	0.009	0.908	**−0.205**	**0.008**
Share of renewable energy in gross final energy consumption (total)	−0.001	0.990	−0.057	0.463	0.055	0.479	**0.280**	**0.001**
Share of renewable energy in gross final energy consumption in transport	0.091	0.241	−0.049	0.528	**0.223**	**0.004**	**0.343**	**0.001**
Share of renewable energy in gross final energy consumption in electricity	0.078	0.315	0.007	0.928	0.123	0.112	**0.165**	**0.033**
Share of renewable energy in gross final energy consumption in heating and cooling	−0.102	0.188	−0.117	0.131	−0.076	0.327	**0.195**	**0.011**
Greenhouse gas emissions intensity of energy consumption	0.020	0.797	0.130	0.093	−0.030	0.699	**−0.189**	**0.014**
Final energy consumption in households per capita	−0.082	0.291	**−0.152**	**0.049**	−0.010	0.898	**0.161**	**0.037**

For most parameters, no significant relationships were found with the number of students studying electricity and energy. Such a relationship occurred only in the case of education at doctoral studies and individual parameters at the bachelor's and master's level. Relationship strength was generally weak. In the case of the share of renewable energy in the economy and its individual sectors, a significant positive correlation between these parameters and the number of doctoral students in electricity and energy was found. Many doctoral dissertations concerned just renewable energy sources. This influenced the interest in a given problem by a wider group of specialists and society. Additionally, the research was carried out in enterprises dealing with energy production or operating in their environment. This could also have contributed to the spread of the idea of using renewable energy sources. In the future, specialists with a doctorate can work and occupy managerial positions in enterprises responsible for energy production. Thus, it can be concluded that along with the higher quality of science, the greater importance of renewable energy sources in the EU countries was noted. In countries educating at doctorate level, the per capita energy consumption was also generally higher. Negative relationships were achieved in the case of energy productivity and greenhouse gas emissions. This was due to the higher energy consumption per person. In countries focusing on education in the fields of electricity and energy, there was greater awareness precisely because of the relatively high energy consumption by society and the resulting problems. Therefore, higher-quality research was put on, such as the work on doctoral dissertations, which was also correlated with smaller negative effects generated on the environment. In other countries, where the problem of energy consumption was smaller, there was simply less interest in very advanced research.

Higher education institutions are strategic actors supporting sustainable development through teaching, research, and social activities [57–59]. Education in universities focused on the CE assumptions allows for the introduction of social and economic changes at the macro and administrative level, supporting enterprises in the implementation of closed-loop processes at the micro level by providing educated employees, implementing experience and innovative projects [46,60–64]. Students are treated as future employees. Particularly in technical faculties, a lot of emphasis is placed on practical classes or design work to prepare students for work in enterprises [65–68].

Some authors point to the association of demographic factors with an increase or a decrease in the number of students [69]. The article adopts the view of other researchers that the number of students is determined by the popularity of a given field of study, i.e., market demand and the possibility of finding a good job [70,71]. In the case of technical studies, cooperation between universities and industry is practiced, dual studies are conducted that allow to work in an industrial enterprise and gain knowledge during studies. Implementation doctorates are also often carried out [72–74].

The studies of other authors confirmed that education in the field of energy studies contributes to the promotion of renewable energy and its greater use by graduates during their work in enterprises and institutions related to energy production and management. On the other hand, the level of knowledge about renewable energy in other fields of study was low, including also in technical fields. Therefore, there is a need to conduct studies that educate precisely in fields related to energy [75–80]. In general, it is also emphasized that there is a great variation between study programs and education in the field of energy and renewable energy in individual countries. Teaching in the field of energy also requires constant adaptation of the curriculum content to the current trends and directions of energy policy [81–84]. In both Europe and the US, programs were not fully adapted to the renewable energy needs of the energy sector. The expert level is gained after years of study and work. Energy students are required to know analytical methods and tools for the implementation of concepts and best design practices in the field of sustainable energy. Many studies emphasize the relationship between education in the fields of energy and the achievement of goals related to balancing energy supplies and achieving the parameters of the circular economy [85–93]. The authors did not find any research relating to the relationship between the number of students in the fields of electricity and energy and the level of achievement of the goals of the circular economy. Therefore, research fills the existing gap.

4. Conclusions

A circular economy in the energy sector is expected to contribute, inter alia, to improvement of energy use and reduction of greenhouse gas emissions. The application and implementation of the related assumptions is largely dependent on general education, but also on specialist education. There were differences in the field of education in the electricity and energy majors in the EU countries. The importance of these majors can be measured, inter alia, with the number of students. It varied from country to country. Additionally, there were differences in the participation of students studying at particular levels. In general, there was the highest number of undergraduate students, because, on average, they constituted 69–72% of all students in the EU studying electricity and energy. There were 24–29% of students at the master's level, respectively, and only 3–4% of PhD students. The higher the level and quality of education, the smaller the number of students. There were slight differences in the structure of the student population in individual countries. There were countries that did not provide special courses in the field of electricity and energy and, for example, did not provide doctoral education. In general, the number of students decreased, the largest decreases were recorded in the case of doctoral and bachelor studies, and the lowest in master studies. However, the level of concentration of student education in the fields of electricity and energy has not changed significantly. Despite this, there were changes inside the EU, because there were countries that increased the number of students, but also drastically reduced it. In general, increases in the number of students were recorded in the more developed countries of Western Europe, while decreases in developing countries in Central and Eastern Europe. Perhaps students go to other countries to study electricity and energy. The number of students in undergraduate and graduate studies was more stable than in doctoral studies, and also in developed countries in the use of renewable energy sources, such as Austria and Finland. The reason for the declines may be market saturation with specialists in the field of electricity and energy. Changes in the number of students may also result from policies pursued at the country level or at the HEIs. Each country should be analyzed separately due to the existing economic and social conditions. The first hypothesis was not verified. The level of concentration of education in the fields of electricity and energy has not changed significantly. The economically developing countries reduced the number of students, while the most economically developed countries increased it.

The research found weak relationships with the parameters assessing the achievement of circular economy assumptions in the energy sector only in the case of doctoral studies. A positive correlation was found in relation to the share of renewable energy in the economy and its sectors. The reason may be that doctoral students conduct research in the field of renewable energy. The research results could be used in practice, but also contributed to the dissemination of the idea of using renewable energy sources. Along with the higher quality of education, the importance of renewable energy in EU countries was noted. Negative relationships were achieved in the case of the relation of the number of students studying electricity and energy to energy productivity and greenhouse gas emissions. Higher-quality research was focused on, such as doctoral dissertations in countries focusing on education in the fields of electricity and energy, which was also correlated with lower negative effects generated on the environment. The interest in very advanced research was lower in countries where the problem of energy consumption was lower. The second hypothesis was positively verified only in relation to education at doctoral studies in electricity and energy. The greater number of students at the level of doctoral studies usually indicated the parameters assessing the achievement of the objectives of the circular economy in the energy sector. It was found that conducting research of the highest quality significantly influences the achievement of the parameters of the circular economy in the energy sector.

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References

1. Jurgilevich, A.; Birge, T.; Kentala-Lehtonen, J.; Korhonen-Kurki, K.; Pietikäinen, J.; Saikku, L.; Schösler, H. Transition towards circular economy in the food system. *Sustainability* **2016**, *8*, 69. [CrossRef]
2. Lieder, M.; Rashid, A. Towards circular economy implementation: A comprehensive review in context of manufacturing industry. *J. Clean. Prod.* **2015**, *115*, 36–51. [CrossRef]
3. Geissdoerfer, M.; Savaget, P.; Bocken, N.M.; Hultink, E.J. The Circular Economy—A new sustainability paradigm? *J. Clean. Prod.* **2017**, *143*, 757–768. [CrossRef]
4. Pomponi, F.; Moncaster, A. Circular economy research in the built environment: A theoretical contribution. In *Building Information Modelling, Building Performance, Design and Smart Construction*; Dastbaz, M., Gorse, C., Eds.; Springer: Cham, Switzerland, 2016.
5. Zink, T.; Geyer, R. Circular economy rebound. *J. Ind. Ecol.* **2017**, *21*, 593–602. [CrossRef]
6. Korhonen, J.; Honkasalo, A.; Seppälä, J. Circular economy: The concept and its limitations. *Ecol. Econ.* **2018**, *143*, 37–46. [CrossRef]
7. Korhonen, J.; Nuur, C.; Feldmann, A.; Birkie, S.E. Circular economy as an essentially contested concept. *J. Clean. Prod.* **2018**, *175*, 544–552. [CrossRef]
8. Prieto-Sandoval, V.; Jaca, C.; Ormazabal, M. Towards a consensus on the circular economy. *J. Clean. Prod.* **2018**, *179*, 605–615. [CrossRef]
9. Morseletto, P. Targets for a circular economy. *Resour. Conserv. Recycl.* **2020**, *153*, 104553. [CrossRef]
10. Stahel, W.R.; Reday-Mulvey, G. *Jobs for Tomorrow: The Potential for Substituting Manpower for Energy*; Vantage Press: New York, NY, USA, 1981.
11. Schulenburg, J.M.; Giarini, O.; Stahel, W.R. The Limits to Certainty. Facing Risks in the New Service Economy (Book Review). *J. Econ.* **1990**, *52*, 95.
12. Stahel, W.R. Resource-miser business models. *Int. J. Environ. Technol. Manag.* **2007**, *7*, 483–495. [CrossRef]
13. Bocken, N.M.; De Pauw, I.; Bakker, C.; Van Der Grinten, B. Product design and business model strategies for a circular economy. *J. Ind. Prod. Eng.* **2016**, *33*, 308–320. [CrossRef]
14. Blomsma, F.; Brennan, G. The emergence of circular economy: A new framing around prolonging resource productivity. *J. Ind. Ecol.* **2017**, *21*, 603–614. [CrossRef]
15. European Union: EU Commission. *Closing the Loop—An Eu Action Plan for the Circular Economy*; Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions COM (2015) 614/2; European Union: Brussels, Belgium, 2015.
16. European Union: European Commission. *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on a Monitoring Framework for the Circular Economy*; COM (2018) 29 Final; European Union: Brussels, Belgium, 2018.
17. Gregson, N.; Crang, M.; Fuller, S.; Holmes, H. Interrogating the circular economy: The moral economy of resource recovery in the EU. *Econ. Soc.* **2015**, *44*, 218–243. [CrossRef]
18. Kirchherr, J.; Piscicelli, L.; Bour, R.; Kostense-Smit, E.; Muller, J.; Huibrechtse-Truijens, A.; Hekkert, M. Barriers to the circular economy: Evidence from the European Union (EU). *Ecol. Econ.* **2018**, *150*, 264–272. [CrossRef]
19. Cheng, M. Sharing economy: A review and agenda for future research. *Int. J. Hosp. Manag.* **2016**, *57*, 60–70. [CrossRef]
20. Ghisellini, P.; Cialani, C.; Ulgiati, S. A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *J. Clean. Prod.* **2016**, *114*, 11–32. [CrossRef]
21. Lewandowski, M. Designing the business models for circular economy—Towards the conceptual framework. *Sustainability* **2016**, *8*, 43. [CrossRef]
22. Sauvé, S.; Bernard, S.; Sloan, P. Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research. *Environ. Dev.* **2016**, *17*, 48–56. [CrossRef]
23. Elia, V.; Gnoni, M.G.; Tornese, F. Measuring circular economy strategies through index methods: A critical analysis. *J. Clean. Prod.* **2017**, *142*, 2741–2751. [CrossRef]
24. Godelnik, R. Millennials and the sharing economy: Lessons from a 'buy nothing new, share everything month'project. *Environ. Innov. Soc. Transit.* **2017**, *23*, 40–52. [CrossRef]

25. Kirchherr, J.; Reike, D.; Hekkert, M. Conceptualizing the circular economy: An analysis of 114 definitions. *Resour. Conserv. Recycl.* **2017**, *127*, 221–232. [CrossRef]
26. Murray, A.; Skene, K.; Haynes, K. The circular economy: An interdisciplinary exploration of the concept and application in a global context. *J. Bus. Ethics* **2017**, *140*, 369–380. [CrossRef]
27. Weber, G.; Cabras, I. The transition of Germany's energy production, green economy, low-carbon economy, socio-environmental conflicts, and equitable society. *J. Clean. Prod.* **2017**, *167*, 1222–1231. [CrossRef]
28. Hens, L.; Block, C.; Cabello-Eras, J.J.; Sagastume-Gutierez, A.; Garcia-Lorenzo, D.; Chamorro, C.; Vandecasteele, C. On the evolution of "Cleaner Production" as a concept and a practice. *J. Clean. Prod.* **2018**, *172*, 3323–3333. [CrossRef]
29. Philippidis, G.; Bartelings, H.; Helming, J.; M'barek, R.; Smeets, E.; Van Meijl, H. The good, the bad and the uncertain: Bioenergy use in the European Union. *Energies* **2018**, *11*, 2703. [CrossRef]
30. Van Meijl, H.; Tsiropoulos, I.; Bartelings, H.; Hoefnagels, R.; Smeets, E.; Tabeau, A.; Faaij, A. On the macro-economic impact of bioenergy and biochemicals–Introducing advanced bioeconomy sectors into an economic modelling framework with a case study for the Netherlands. *Biomass Bioenergy* **2018**, *108*, 381–397. [CrossRef]
31. Wang, J.; Yang, Y.; Bentley, Y.; Geng, X.; Liu, X. Sustainability assessment of bioenergy from a global perspective: A review. *Sustainability* **2018**, *10*, 2739. [CrossRef]
32. Ubando, A.T.; Felix, C.B.; Chen, W.H. Biorefineries in circular bioeconomy: A comprehensive review. *Bioresour. Technol.* **2020**, *299*, 122585. [CrossRef]
33. Geng, Y.; Doberstein, B. Developing the circular economy in China: Challenges and opportunities for achieving'leapfrog development'. *Int. J. Sustain. Dev. World Ecol.* **2008**, *15*, 231–239. [CrossRef]
34. Mathews, J.A.; Tan, H. Progress toward a circular economy in China: The drivers (and inhibitors) of eco-industrial initiative. *J. Ind. Ecol.* **2011**, *15*, 435–457. [CrossRef]
35. Geng, Y.; Fu, J.; Sarkis, J.; Xue, B. Towards a national circular economy indicator system in China: An evaluation and critical analysis. *J. Clean. Prod.* **2012**, *23*, 216–224. [CrossRef]
36. Williams, E.; Kahhat, R.; Bengtsson, M.; Hayashi, S.; Hotta, Y.; Totoki, Y. Linking informal and formal electronics recycling via an interface organization. *Challenges* **2013**, *4*, 136–153. [CrossRef]
37. Gu, Y.; Wu, Y.; Xu, M.; Wang, H.; Zuo, T. The stability and profitability of the informal WEEE collector in developing countries: A case study of China. *Resour. Conserv. Recycl.* **2016**, *107*, 18–26. [CrossRef]
38. Petit-Boix, A.; Leipold, S. Circular economy in cities: Reviewing how environmental research aligns with local practices. *J. Clean. Prod.* **2018**, *195*, 1270–1281. [CrossRef]
39. Liakos, N.; Kumar, V.; Pongsakornrungsilp, S.; Garza-Reyes, J.A.; Gupta, B.; Pongsakornrungsilp, P. Understanding circular economy awareness and practices in manufacturing firms. *J. Enterp. Inf. Manag.* **2019**, *32*, 563–584. [CrossRef]
40. Ngan, S.L.; How, B.S.; Teng, S.Y.; Promentilla, M.A.B.; Yatim, P.; Er, A.C.; Lam, H.L. Prioritization of sustainability indicators for promoting the circular economy: The case of developing countries. *Renew. Sustain. Energy Rev.* **2019**, *111*, 314–331. [CrossRef]
41. Virtanen, M.; Manskinen, K.; Uusitalo, V.; Syvänne, J.; Cura, K. Regional material flow tools to promote circular economy. *J. Clean. Prod.* **2019**, *235*, 1020–1025. [CrossRef]
42. Fonseca, L.M.; Domingues, J.P.; Pereira, M.T.; Martins, F.F.; Zimon, D. Assessment of Circular Economy within Portuguese Organizations. *Sustainability* **2018**, *10*, 2521. [CrossRef]
43. Stahel, W.R. The circular economy. *Nature* **2016**, *531*, 435–438. [CrossRef]
44. Kılkış, Ş.; Kılkış, B. Integrated circular economy and education model to address aspects of an energy-water-food nexus in a dairy facility and local contexts. *J. Clean. Prod.* **2017**, *167*, 1084–1098. [CrossRef]
45. Pomponi, F.; Moncaster, A. Circular economy for the built environment: A research framework. *J. Clean. Prod.* **2017**, *143*, 710–718. [CrossRef]
46. Merli, R.; Preziosi, M.; Acampora, A. How do scholars approach the circular economy? A systematic literature review. *J. Clean. Prod.* **2018**, *178*, 703–722. [CrossRef]
47. Kirchherr, J.; Piscicelli, L. Towards an education for the circular economy (ECE): Five teaching principles and a case study. *Resour. Conserv. Recycl.* **2019**, *150*, 104406. [CrossRef]
48. Fonseca, L.M.; Portela, A.R.; Duarte, B.; Queirós, J.; Paiva, L. Mapping higher education for sustainable development in Portugal. *Manag. Mark. Chall. Knowl. Soc.* **2018**, *13*, 1064–1075. [CrossRef]

49. Dixon, P.M.; Weiner, J.; Mitchell-Olds, T.; Woodley, R. Erratum to 'Bootstrapping the Gini Coefficient of Inequality. *Ecology* **1988**, *69*, 1307. [CrossRef]
50. Dagum, C. The Generation and Distribution of Income, the Lorenz Curve and the Gini Ratio. *Econ. Appliquée* **1980**, *33*, 327–367.
51. Starzyńska, W. *Statystyka Praktyczna*; Wydawnictwo Naukowe PWN: Warszawa, Poland, 2002; p. 102.
52. Abdi, H. Coefficient of variation. *Encycl. Res. Des.* **2010**, *1*, 169–171.
53. Jajuga, K.; Walesiak, M. Remarks on the Dependence Measures and the Distance Measures. In *Klasyfikacja i Analiza Danych-Teoria i Zastosowania*; Jajuga, K., Walesiak, M., Eds.; Prace Naukowe Akademii Ekonomicznej we Wrocławiu nr 1022; AE: Wrocław, Poland, 2004; pp. 348–354.
54. Atkinson, A.B. *The Economics of Inequality*; Clarendon Press: Oxford, UK, 1983; pp. 46–59.
55. Lorenz, M.O. Methods of Measuring the Concentration of Wealth. *Publ. Am. Stat. Assoc.* **1905**, *9*, 209–219. Available online: https://www.jstor.org/stable/2276207 (accessed on 10 July 2020). [CrossRef]
56. Hauke, J.; Kossowski, T. Comparison of Values of Pearson's and Spearman's Correlation Coefficients on the Same Sets of Data. *Quaest. Geogr.* **2011**, *30*, 87–93. [CrossRef]
57. Pandey, N.; Vedak, V. Structural transformation of education for sustainable development. *Int. J. Environ. Sustain. Dev.* **2010**, *9*, 3–15. [CrossRef]
58. Berryman, T.; Sauvé, L. Ruling relationships in sustainable development and education for sustainable development. *J. Environ. Educ.* **2016**, *47*, 104–117. [CrossRef]
59. Mendoza, J.M.F.; Gallego-Schmid, A.; Azapagic, A. Building a business case for implementation of a circular economy in higher education institutions. *J. Clean. Prod.* **2019**, *220*, 553–567. [CrossRef]
60. Zografakis, N.; Menegaki, A.N.; Tsagarakis, K.P. Effective education for energy efficiency. *Energy Policy* **2008**, *36*, 3226–3232. [CrossRef]
61. Kopnina, H. Circular economy and Cradle to Cradle in educational practice. *J. Integr. Environ. Sci.* **2018**, *15*, 119–134. [CrossRef]
62. Kopnina, H. Green-washing or best case practices? Using circular economy and Cradle to Cradle case studies in business education. *J. Clean. Prod.* **2019**, *219*, 613–621. [CrossRef]
63. Colombo, E.; Mattarolo, L. Energy and development: The role of academia in education, research, and technological cooperation for sustainability. *Wiley Interdiscip. Rev. Energy Environ.* **2017**, *6*, e215. [CrossRef]
64. João, I.M.; Silva, J.M. Sustainable product design education: Engineering students' perceptions and attitudes. In Proceedings of the 2020 IEEE Global Engineering Education Conference (EDUCON), Porto, Portugal, 27–30 April 2020; pp. 150–157.
65. Connor, A.; Karmokar, S.; Whittington, C. From STEM to STEAM: Strategies for enhancing engineering & technology education. *Int. J. Eng. Pedagog.* **2015**, *5*, 37–47.
66. Lucas, B.; Hanson, J. Thinking like an engineer: Using engineering habits of mind and signature pedagogies to redesign engineering education. *Int. J. Eng. Pedagog.* **2016**, *6*, 4–13. [CrossRef]
67. Whalen, K.A.; Berlin, C.; Ekberg, J.; Barletta, I.; Hammersberg, P. 'All they do is win': Lessons learned from use of a serious game for Circular Economy education. *Resour. Conserv. Recycl.* **2018**, *135*, 335–345. [CrossRef]
68. Admiraal, W.; Post, L.; Guo, P.; Saab, N.; Makinen, S.; Rainio, O.; Danford, G. Students as future workers: Cross-border multidisciplinary learning labs in higher education. *Int. J. Technol. Educ. Sci.* **2019**, *3*, 85–94.
69. Clauss-Ehlers, C.S.; Parham, W.D. Landscape of diversity in higher education: Linking demographic shifts to contemporary university and college counseling center practices. *J. Multicult. Couns. Dev.* **2014**, *42*, 69–76. [CrossRef]
70. Mizikaci, F.; Baumgartl, B. Demographic trends and risks for European higher education. *Int. Higher Educ.* **2007**, *47*, 15–16. [CrossRef]
71. Nellis, J.G.; Nellis, H.G.; Slattery, D. The challenges and prospects for higher education in the context of global change. *Int. J. Econ. Bus. Res.* **2013**, *5*, 347–361. [CrossRef]
72. Arlett, C.; Lamb, F.; Dales, R.; Willis, L.; Hurdle, E. Meeting the needs of industry: The drivers for change in engineering education. *Eng. Educ.* **2010**, *5*, 18–25. [CrossRef]
73. Dean, S.; Hopkins, A. Aspects of mutual engagement: School of engineering and industry collaborations. *Higher Educ. Pedagog.* **2016**, *1*, 30–41.
74. Janicki, T.N.; Cummings, J. Increasing Student/Corporate Engagement. *Inf. Syst. Educ. J.* **2017**, *15*, 37.
75. Acikgoz, C. Renewable energy education in Turkey. *Renew. Energy* **2011**, *36*, 608–611. [CrossRef]

76. Karabulut, A.; Gedik, E.; Keçebaş, A.; Alkan, M.A. An investigation on renewable energy education at the university level in Turkey. *Renew. Energy* **2011**, *36*, 1293–1297. [CrossRef]
77. Qu, M.; Ahponen, P.; Tahvanainen, L.; Gritten, D.; Mola-Yudego, B.; Pelkonen, P. Chinese university students' knowledge and attitudes regarding forest bio-energy. *Renew. Sustain. Energy Rev.* **2011**, *15*, 3649–3657. [CrossRef]
78. Zyadin, A.; Puhakka, A.; Ahponen, P.; Cronberg, T.; Pelkonen, P. School students' knowledge, perceptions, and attitudes toward renewable energy in Jordan. *Renew. Energy* **2012**, *45*, 78–85. [CrossRef]
79. Mälkki, H.; Alanne, K.; Hirsto, L. A method to quantify the integration of renewable energy and sustainability in energy degree programmes: A Finnish case study. *J. Clean. Prod.* **2015**, *106*, 239–246. [CrossRef]
80. Sucic, B.; Lah, P.; Visocnik, B.P. An education and training program for energy managers in Slovenia–Current status, lessons learned and future challenges. *J. Clean. Prod.* **2017**, *142*, 3360–3369. [CrossRef]
81. Perkins, J.H.; Middlecamp, C.; Blockstein, D.; Cole, J.R.; Knapp, R.H.; Saul, K.M.; Vincent, S. Energy education and the dilemma of mitigating climate change. *J. Environ. Stud. Sci.* **2014**, *4*, 354–359. [CrossRef]
82. Figueiró, P.S.; Raufflet, E. Sustainability in higher education: A systematic review with focus on management education. *J. Clean. Prod.* **2015**, *106*, 22–33. [CrossRef]
83. Dlouhá, J.; Glavič, P.; Barton, A. Higher education in Central European countries–Critical factors for sustainability transition. *J. Clean. Prod.* **2017**, *151*, 670–684. [CrossRef]
84. Ruiz-Rivas, U.; Martinez-Crespo, J.; del Carmen Venegas-Bernal, M.; Chinchilla-Sanchez, M. Energy engineering curricula for sustainable development, considering underserved areas. *J. Clean. Prod.* **2020**, *258*, 120960. [CrossRef]
85. Klein, G.A.; Hoffman, R.R. Seeing the invisible: Perceptual-cognitive aspects of expertise. *Cogn. Sci. Found. Instr.* **1993**, 203–226. Available online: https://cmapspublic3.ihmc.us/rid=1G9NSY15K-N7MJMZ-LC5/SeeingTheInvisible.pdf (accessed on 10 July 2020).
86. Mihelcic, J.R.; Crittenden, J.C.; Small, M.J.; Shonnard, D.R.; Hokanson, D.R.; Zhang, Q.; Schnoor, J.L. Sustainability science and engineering: The emergence of a new metadiscipline. *Environ. Sci. Technol.* **2003**, *37*, 5314–5324. [CrossRef]
87. Jennings, P. New directions in renewable energy education. *Renew. Energy* **2009**, *34*, 435–439. [CrossRef]
88. Batterman, S.A.; Martins, A.G.; Antunes, C.H.; Freire, F.; da Silva, M.G. Development and application of competencies for graduate programs in energy and sustainability. *J. Prof. Issues Eng. Educ. Pract.* **2011**, *137*, 198–207. [CrossRef]
89. Guinee, J.B.; Heijungs, R.; Huppes, G.; Zamagni, A.; Masoni, P.; Buonamici, R.; Rydberg, T. Life cycle assessment: Past, present, and future. *Environ. Sci. Technol.* **2011**, *45*, 90–96. [CrossRef] [PubMed]
90. Malkki, H.; Alanne, K.; Hirsto, L. Energy engineering students on their way to expertise in sustainable energy. *Environ. Clim. Technol.* **2012**, *8*, 24–28. [CrossRef]
91. Gelegenis, J.J.; Harris, D.J. Undergraduate studies in energy education—A comparative study of Greek and British courses. *Renew. Energy* **2014**, *62*, 349–352. [CrossRef]
92. Harris, D.J.; Gelegenis, J.J. Energy engineering: An emerging discipline. In *Engineering Education. Curriculum, Pedagogy and Didactic Aspects*; Oxford University Press: Oxford, UK, 2014; pp. 145–163.
93. Nowotny, J.; Dodson, J.; Fiechter, S.; Gür, T.M.; Kennedy, B.; Macyk, W.; Rahman, K.A. Towards global sustainability: Education on environmentally clean energy technologies. *Renew. Sustain. Energy Rev.* **2018**, *81*, 2541–2551. [CrossRef]