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Analysis of Primary Energy Factors from Photovoltaic Systems for a Nearly Zero Energy Building (NZEB): A Case Study in Lithuania

Rokas Tamašauskas [1], Jolanta Šadauskienė [2], Dorota Anna Krawczyk [3,*] and Violeta Medelienė [4]

1 JSC Planuotojai, Vasario 16-osios str. 8-6, LT-44250 Kaunas, Lithuania; rokas.tamasauskas@gmail.com
2 Faculty of Civil Engineering and Architecture, Kaunas University of Technology, Studentų Street 48, LT-51367 Kaunas, Lithuania; jolanta.sadauskiene@ktu.lt
3 Faculty of Civil Engineering and Environmental Sciences, Bialystok University of Technology, Wiejska 45 E, 15-351 Bialystok, Poland
4 Faculty of Engineering Sciences, University of Applied Engineering Sciences, Tvirtovės av. 35, LT-50155 Kaunas, Lithuania; violeta.madeliene@edu.ktk.lt
* Correspondence: d.krawczyk@pb.edu.pl

Received: 21 July 2020; Accepted: 2 August 2020; Published: 7 August 2020

Abstract: Following a new climate and energy plan, the European Union (EU) gives big attention to energy savings. The overall assessment of energy saving measures is very important. Thus, it is crucial to estimate in a proper way the primary energy factor, which is used in calculations of primary energy consumption from renewable energy (RE) sources in a Nearly Zero Energy Building (NZEB). The conduced studies of the literature and national regulations showed that different methods to determine energy from photovoltaic (PV) systems are used. The aim of this paper is to evaluate the primary energy factors of energy from photovoltaics and determine the average value. To achieve this aim, the data of 30 photovoltaic systems from Lithuania were analyzed. The results show a 35% diversification in the values of non-renewable primary energy factor, depending on the PV systems' capacities, with the average on a level of 1.038.

Keywords: primary energy factor; renewable energy sources; photovoltaic system; energy efficiency; low energy buildings

1. Introduction

1.1. Overview on Renewable Energy

At the turn of the 20th and 21st centuries, increased impacts on the environment were observed, and thus studies on sustainable development as well as actions aimed to mitigate climate change became more popular [1]. The United Nations Framework on Climate Change (UNFCCC) in 1992 set the background for the limitation of greenhouse gas emissions, as actions in this area were found to be essential for the prevention of doom-laden environmental consequences [2]. Additionally, the United Nations proposed the 17 Sustainable Development Goals in 2015, including topics related to ways of reducing greenhouse gas emissions [3]. Most attention was focused on the energy field and especially on the building sector. Existing buildings consume about 40% of the EU's total energy and cause above one third of its CO_2 emissions [4]. This is despite the progress made in implementing energy efficiency policies under national plans and actions. Thus, Member States do their best to meet the requirements of Directive 2006/32/EC of the European Parliament and of the council of 5 April 2006 on energy end-use efficiency. However, still the union has hardly succeeded in achieving its energy efficiency targets. An initial analysis of the second Action Plans in 2011 confirmed that the union is not on the right course. Thus, the union's legal framework for energy efficiency was updated with the Directive 2012/27/EU, trying to obtain the overall assumed objectives for energy efficiency and reach a goal set at a level of 20% of the union's primary energy consumption by 2020. Moreover, subsequent improvements in the area of energy efficiency are planed after 2020 [5]. Against the backdrop of planned actions, the European energy targets have been subjected to progressive efforts to replace fossil fuels by sustainable and renewable systems [6]. These efforts have altered investments in the energy market. The investments in the renewable energy sector increased by 55% from 2010 to 2018 [7]. European countries expanded renewable energy facilities, such as photovoltaics (PV) and wind power. This resulted in 5% fall in the European greenhouse gas emissions related to electricity production in 2018 [8].

Looking at future plans, Directive 2018/2001/EU has established a binding union target of a share of at least 32% of renewable energy. The European Union has adopted a new climate and energy plan of strategy which increases the usage of renewable energy by more than 27% by 2030 [9]. Taking into account the differentiation of climatic conditions and building traditions in EU countries, Member States commit themselves to developing national targets; increasing the number of energy-efficient buildings, such as Nearly Zero Energy Buildings (NZEBs); defining the primary energy demand that is needed for heating, cooling, ventilation (HVAC), and domestic hot water (DHW) preparation; and using renewable energy sources in the building sector [10–15]. To meet the EU's energy and climate targets for 2030, the EU Member States established an integrated national energy and climate plan for the period from 2021 to 2030 [16].

Lithuania, like other EU countries, approved the national strategy "National Energy Independence Strategy of the Republic of Lithuania" in 2018 [17]. In line with this document, Lithuania has set ambitious targets to make a significant contribution to the Energy Union and the implementation of the policy objectives of the EU energy and climate framework. Lithuania, together with Latvia and Estonia, will synchronize with Poland for a reliable and unified power system for continental Europe by 2025. By 2030, a 45% share of renewable energy in final energy consumption is expected to be achieved (one of the biggest ambitions for the development of renewable energy sources in the EU), of which 45% in electricity and 90% in district heating will come from renewable energy sources. Additionally, at least 30% of consumers will generate electricity for their own usage. The share of domestic electricity production in Lithuania will increase in the range from 35% to 70% [17].

Reviewing the trends of the last decade in terms of the energy sector in Lithuania, it was noted that the gross inland fuel and energy consumption in the country has decreased by about 10%, and renewable energy sources are a significant contributor to the development of the national economy. Simultaneously, their share in electricity production been raised from 7.7% to 9.7%, whereas the Lithuanian final fuel and energy consumption has changed by about 12%. Moreover, there is a visible increase (from 21.4% to 25.6%) in the share of renewable energy sources in the gross final fuel and energy balance. Contemporaneously, the share of renewable energy sources in the gross final electricity consumption changed from 10.9% to 16.8%, while in the case of the gross final heating and cooling consumptions the change was noted to be from 34.6% to 46.5% [12].

1.2. Utilization of Renewable Energy in Buildings

The legal requirements for the new generation buildings are described in the amended text of the Energy Performance of Buildings Directive (EPBD) [18] and the Energy Efficiency Directive (EED) [19]. According to those documents, EU countries must increase their energy efficiency targets, expressed in the primary and/or total energy consumption, by at least 32.5% by 2030. In order to implement the EU targets, the energy efficiency of NZEB is evaluated as the balance of renewable and non-renewable energy. The NZEB concept is usually defined as a building that is neutral over a specific period of time (a year)—that is, it delivers similar amount of energy to the supply grids as it charges from these grids [20–23]. It means that the supplied energy from renewable energy sources to the NZEB boundary is a mixture of renewable and non-renewable energy.

Figure 1 demonstrates the supply chain, starting from the primary energy from renewable sources and ending in its usage in a building. All the direct and indirect energy transformations that are part of the electricity generation process were indicated, including the energy spent on extraction, transportation, and transformation, and it takes into account the real share of renewable energy sources.

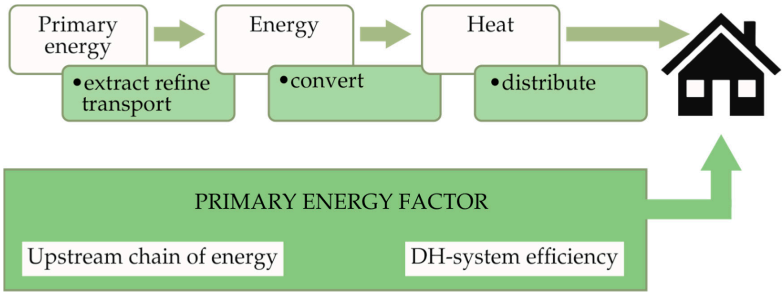

Figure 1. Scheme of the primary energy supply chain based on renewable sources.

Renewable electricity generation and consumption differ due to climate conditions, the season of the year, and the time of day. For example, in the case of photovoltaic systems connected to the local electricity grid, the electricity produced during the day can be used immediately in the building or transmitted to the electricity grid. In the evening, when the photovoltaic system is not working, electricity is supplied from the mains. No battery is required for this type of system [24]. For these reasons, the lack of electricity available at the peak of electricity consumption can appear. In addition, conversion devices consume renewable energy during periods of low electricity consumption, or they can even discharge electricity to the grid while the needs are high. In those cases, conversion devices normally use additional non-renewable energy (for instance, any fuels) [25,26].

Directive 2018/2002/EU (indent 21) states the importance of considering all the steps in the energy chain while calculating the energy savings in order to multiply the potential of savings in electricity transmission and distribution [9]. The Primary Energy Factor (PEF), described also as the conversion factor, helps to evaluate the primary energy consumption, including the chain of energy generation based on the final energy consumption data (Figure 1). It shows the amount of primary energy used to produce a unit of electricity or, in specific situations, the unitary useable thermal energy.

1.3. Evaluation of Primary Energy Factor

Directive 2018/2002/EU (indent 40) provides three methods for setting the PEF value:

- "physical energy content"—a method used for the generation of nuclear electricity and heat;
- "technical conversion efficiency"—a method used for the production of electricity and heat from biomass and different fossil fuels;
- "total primary energy"—a method that is used for non-combustible renewable energy.

The basic guidelines of the "total primary energy" method are provided in EN 15603:2014 [27]. It suggests that the PEF of electricity can be obtained when we divide the raw primary energy demand of electricity generation by the electricity produced, in cases when only the generation of energy is taken into account. The basic idea of the primary energy balance performed in EN 15603:2014 [27] is that each energy flow crossing the assessment boundary is characterized by the total associated primary energy and is given by sum of the non-renewable PEF ($f_{P,nren}$) and renewable PEF ($f_{P,ren}$) (Figure 2).

According to Directive 2018/2002/EU (indent 40), 100% conversion efficiencies are assumed in the case of non-combustible renewables, and the PEF ($f_{P,ren}$) is 1 for all energy sources for the system boundaries. However, the PEF value of non-renewable energy ($f_{P,nren}$), which includes transmission and distribution losses, is cannot easily determined. Depending on the type of primary energy and regarding the calculation method used, the primary energy factor may differ significantly for the same renewable energy source [24,28]. The analysis of the latest scientific studies [29–33] showed that primary energy is evaluated by different methods:

- "Zero-equivalent method". This method does not evaluate the electrical and thermal energy production from renewables, thus, in this case, the total primary energy factor is considered as $f_{P,tot} = 0$ [29].
- "Direct equivalent". In this case, the electrical and thermal energy production from non-fossil renewable energy as well as nuclear energy sources are taken into consideration, thus $f_{P,tot} = 1$ [30].
- "Amount of physical energy". This method evaluates the primary form of energy obtained in the generation process and sets the factor as $f_{P,tot} = 1$ [31].
- The "Alternate" method takes into account the primary form of energy. It is included in the statistical energy balance before the conversion to the secondary or tertiary form of energy, so the factor is relatively high and amounts to $f_{P,tot} = 2.5$ [32,33].
- The "Effectiveness of technical conversion" method. It considers the entire energy generation chain, with the assumption of independent estimations of both renewable and non-renewable energy, resulting in a non-renewable primary energy factor $f_{P,nren} = 0.032$ and a renewable primary energy factor $f_{P,ren} = 2.5$ [32,33].
- "Amount of physical energy". This method evaluates the primary form of energy from the generation process and recommends the values of factors $f_{P,nren} = 0.032$ and $f_{P,ren} = 1$ [31].

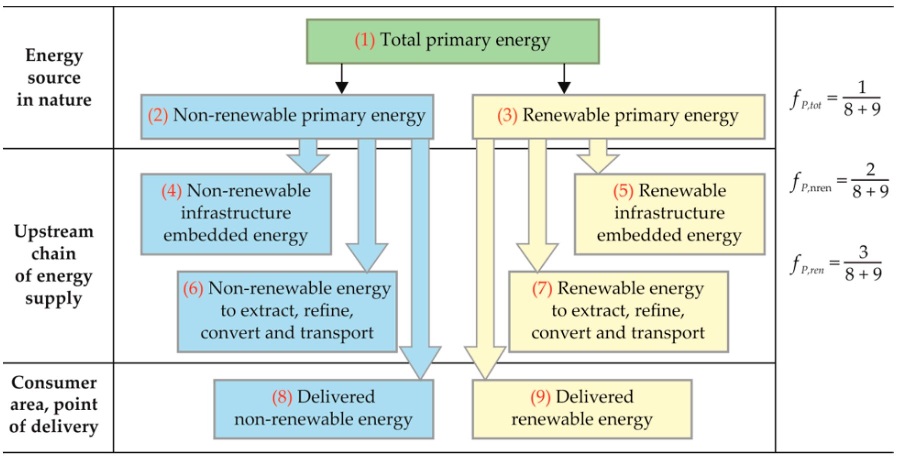

Figure 2. Schema of energy flows (own elaboration based on [27]).

The analysis shows that different methodologies use various PEF values for the evaluation of photovoltaic systems, thus the results are not comparable or useful for general studies. The analysis of PEF calculation options for electricity performed by Esser and Sensfuss [25] showed that the actually used methodology was outdated and needed a review. The PEF set at a level of 2.5 reflected the old data for the European power system, while it does not refer to the current energy market with a significant share of renewable sources in the power generation balance. As noted, in 2015 the average renewable energy sources share for electricity in the EU was 28%, and it is increasing continuously to meet a projected 45% level by 2030, based on the EU renewable energy sources' target.

The outcomes of the literature review are that the information about the setting of PEF values is not sufficient; the PEF values varied for the same type of energy, and several diversified methodologies were used for calculations. It is crucial to set a proper PEF value, as just accurate data on photovoltaic renewable ($f_{P,ren}$) and non-renewable ($f_{P,nren}$) primary factors could allow the objective estimation of the amount of renewable and non-renewable primary energy consumed in NZEB buildings. Therefore, this paper's aim is to investigate and evaluate the primary factors. The proposal of this work is also to estimate the average value of the primary energy factor as the energy factor of energy from photovoltaic systems, based on the data of the produced and consumed energy, as it intends to investigate its dependence on the capacity of PV systems. A detailed case study of the Lithuanian photovoltaic energy could be later used as a template for a similar analysis to be carried out for other national markets, and the foundlings can be relevant to policy makers.

The structure of this work consists of four sections: Methodology, Results, Discussion, and Conclusion. The research object, climate data, and primary energy calculation methodology are provided in the Methodology section. The section on the results provides a concise description of the experimental results and their interpretation. In the section on the discussion, the results are provided to be interpreted in a context of other studies and this working hypothesis. The study findings are discussed in the EU law and recommendations background. The final and significant outcomes are provided in the section on the conclusion.

2. Methodology

2.1. Research Object

The statistical data from the year 2018 suggests that the total number of photovoltaic (PV) systems in Lithuania was 3050, in which the sum of the installed capacity was 88 MW. The amount of total produced energy was 67 GWh.

Data for the investigation were collected from 30 PV systems operating in Lithuania by interviewing PV system owners/operators and by taking into account the outcomes from the reports of electricity transmission system operators in the country. The data of the produced and consumed energy were collected over the period of 2014–2018. The PV systems were divided into groups of different capacities: group A > 20 (kW); group 20 > B > 10 (kW); and group C < 10 (kW). The main characteristics of the investigated PV systems are presented in Table 1.

Table 1. The main characteristics of the investigated photovoltaic (PV) systems.

Mark	Type of Module	Total Installed Power Capacity, kw	Tilt Angle, °C	Produced Electrical Energy E_p, kWh/year	Consumed Electrical Energy E_c, kWh/Year
1A	aSi/uSi	28.24	43	40,043	128
2A	Mono-Si	28.80	38	28,137	360
3A	Mono-Si	29.28	35	25,265	310
4A	aSi/uSi	29.76	38	30,048	163
5A	aSi/uSi	29.76	40	30,226	144
6A	Mono-Si	29.89	38	31,600	260
7A	Poly-Si	3.000	49	31,607	230
8A	Poly-Si	3.000	38	29,018	150
9A	Mono-Si	3.000	48	29,369	172
10A	Poly-Si	3.000	36	32,609	310
1B	aSi/uSi	1.000	31	14,583	102
2B	Poly-Si	1.290	30	11,257	33
3B	Poly-Si	1.176	38	10,789	147
4B	aSi/uSi	13.52	38	10,726	136
5B	Mono-Si	14.40	36	14,537	106
6B	aSi/uSi	14.94	31	13,520	136
7B	CIS	16.80	34	11,608	76
8B	Poly-Si	18.00	48	14,560	178
9B	Poly-Si	18.00	38	10,563	122
10B	Mono-Si	19.95	40	13,009	116
1C	Mono-Si	1.00	30	4849	121
2C	Poly-Si	1.96	38	8971	180
3C	Poly-Si	3.00	33	3850	133
4C	Poly-Si	3.12	34	4757	118
5C	Mono-Si	4.00	35	3091	106
6C	aSi/uSi	4.75	33	4589	100
7C	CIS	6.00	38	9975	165
8C	Poly-Si	7.50	31	9429	155
9C	Mono-Si	9.50	30	6389	176
10C	Poly-Si	9.66	35	9584	180

2.2. Climate Data

Lithuania is in the south-western sub-area of the Atlantic continental zone. Lithuania is between the parallel of the 54° and 56° north latitude. Thus, in June, the height of the sun is 58.5°; in December, it is 11.5°; and on the equinox of spring and autumn, it is 35°. At noon on a sunny day, at the indicated times of the year, the Lithuanian surface receives, respectively, 86%, 21%, and 57% of solar energy, regarding the average amount of energy on Earth above the sea surface. Respectively, the length of the day varies from 17.3 h in midsummer to 12 h on the equinoxes and up to 7.2 h in midwinter.

The average annual solar radiation impinging onto the horizontal surface of Lithuania reaches approximately 1000 kWh/m^2. Sunlight lasts the longest in the western part (1840–1900 h/year) and shortens while moving towards the east (1700 h/year) (Figure 3).

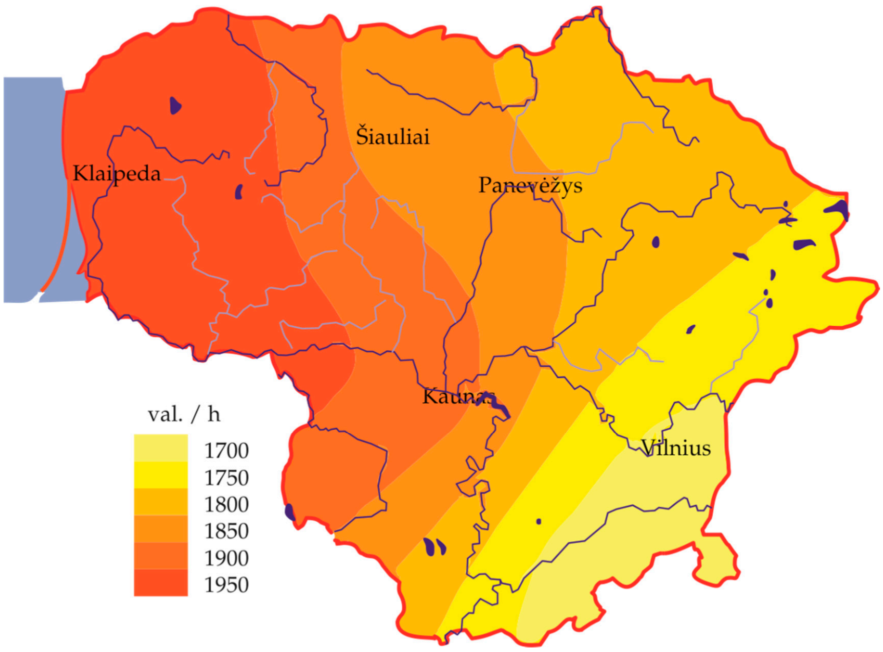

Figure 3. Average annual duration of sunshine in Lithuania. Standard climate norm, 1981–2010 [34].

The generative efficiency of photovoltaic power stations is directly dependent on solar radiation. In order to use solar radiation to its maximum under the Lithuanian climate conditions, photovoltaic modules must be directed towards the south a with 30°–60° lean angle from the horizontal plane. Such an orientation of one square meter of the area of a photovoltaic power station generates 130–160 kWh electrical energy annually under the Lithuanian climate conditions.

2.3. Primary Energy Calculation Methodology

The total primary energy factor may be calculated using the Equation (1) according to the regulations of EN 15603: 2014 [27].

$$f_{P,tot} = f_{P,nren} + f_{P,ren}, \tag{1}$$

where $f_{P,tot}$ is the total primary energy factor; $f_{P,nren}$ is the non-renewable primary energy factor; $f_{P,ren}$ is the renewable primary energy factor.

The analysis is based on the assumption that all of the energy supplied to the building is attributable to renewable energy because it is made from renewable PV energy. Accordingly, the renewable primary energy factor $f_{P,ren}$ is equal to 1. The value of the efficiency of electricity production η_{el} and the losses of electricity transportation e_T were evaluated by the calculations. The building normative documents of Lithuania for building electricity consumption calculations indicate that e_T = 0 and η_{el} = 2.8 [35].

The value of the primary non-renewable energy factor $f_{P,nren}$ produced by the PV system is given by the Equation (2), which is provided in EN 15603: 2014 [27]:

$$f_{P,nren} = \frac{E_p \cdot e_T + E_c \cdot \eta_{el}}{E_p + E_c}, \tag{2}$$

where E_c is the amount of consumed energy in kWh/year; E_p is the amount of produced energy in kWh/year; η_{el} is the coefficient of the efficiency of electricity production (η_{el} = 2.8); e_T is the coefficient of the losses of electricity transportation (e_T = 0).

The calculation of the value of PEF of the electricity produced by PV systems was performed according to the data provided by the power systems (Table 2).

Table 2. The result of the Primary Energy Factor (PEF) calculation.

Indicators	**The Values of the Capacities of the PV Systems Operated in Lithuania**			**Weighted Average**
	A > 20 (kW)	**20 > B > 10 (kW)**	**C < 10 (kW)**	**-**
$f_{P,nren}$	0.021	0.028	0.065	0.038
$f_{P,ren}$	1	1	1	1
$f_{P,tot}$	1.021	1.028	1.065	1.038

The descriptive statistics were applied in this study. In order to estimate reliably the mean of the range μ, the sample mean $\overline{x}$ was estimated (Equation (3)):

$$\overline{x} = \frac{1}{n}, \tag{3}$$

where:

n is the number of items in a sample; j is the variable (j = 1,2, … n).

The mean of the range μ is calculated according to the mathematical expression (Equation (4)):

$$\mu = \frac{1}{N}\sum_{j=1}^{N} x_j, \tag{4}$$

where:

N is the number of items in the population; j is the variable (j = 1,2, … n).

3. Results

In order to determine the PEF, first of all the overall balance of the generated and consumed electric power in the analyzed PV systems was investigated. The results of the analysis of the average monthly distribution of the produced and consumed electric power in A, B, and C groups of the studied PV systems are presented in Figure 4.

The average annual consumption percentage value from the total produced electricity amount of the PV systems of A group equals 0.7%. In the case of the PV systems of group B, the average annual consumption percentage value from the total produced electricity amounts to 0.9%. Finally, the average annual consumption percentage value for the C group of PV systems reaches 2.2%. Thus, the obtained results suggest that there is no relation between the produced and consumed electrical energy in the PV systems.

Figure 5 shows the probability density function of the consumed electrical energy of PV systems, which has a normal Gauss distribution. That means that the electricity consumption is almost constant each month. The fluctuations are small and can be explained by hardware factors. The obtained analysis results allow us to reliably determine the PEF values.

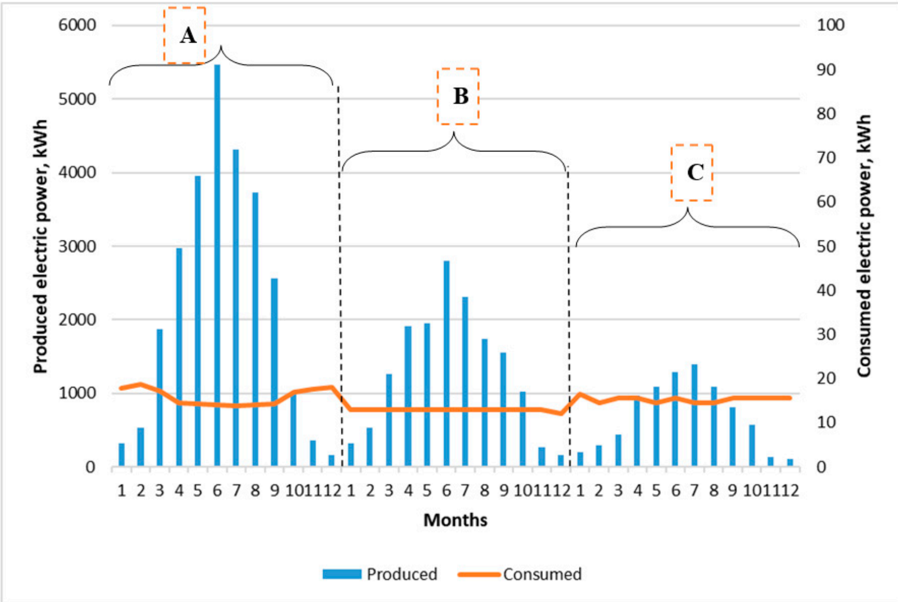

Figure 4. The average values of the balance of the produced and consumed electric power per year.

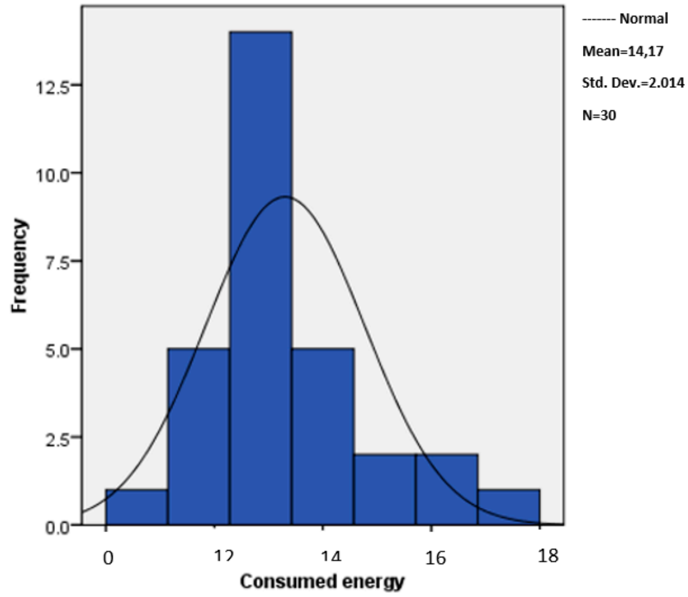

Figure 5. The frequency distribution of values of the consumed electrical energy of PV systems.

As was mentioned before, the PEF or $f_{P,tot}$ (they are the same) values consist of photovoltaic renewable ($f_{P,ren}$) and non-renewable ($f_{P,nren}$) primary factors. The renewable primary energy factor $f_{P,ren}$ is equal to 1, according to the directive [18]. Hence, the non-renewable primary energy factor $f_{P,nren}$ was determined after the assignment of analyzed PV systems to groups of different capacities (A, B, and C). The results of the calculated $f_{P,nren}$ factors of the studied PV systems are presented in Figure 6.

The data presented in Figure 6 show that the average numeric indicator of the $f_{P,nren}$ factor in PV systems is 0.038 (the dotted line). The average numerical value of the $f_{P,nren}$ indicator for PV systems of A group, where the capacity of PV systems is more than 20 (kW), equals 0.021. A similar result was found in B group, where the capacity of PV systems is 20–10 (kW), and the average of $f_{P,nren}$ equals 0.028. However, the average of the $f_{P,nren}$ value for C group (capacity is less than 10 (kW)) reaches 0.065.

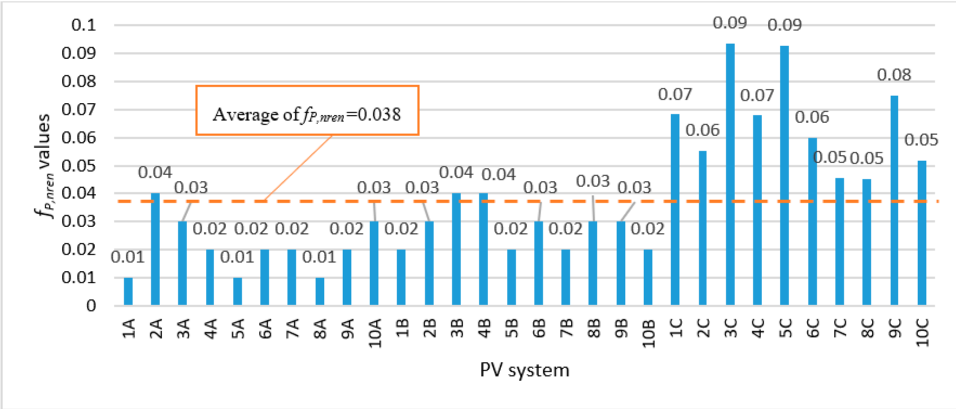

Figure 6. Relationship between f_{Pnren} and PV power in PV systems.

The lowest $f_{P,nren}$ indicator (the value 0.01) was estimated for the 1A, 5A, and 8A power stations, and the highest $f_{P,nren}$ value 0.09 was for the 3C and 5C investigated PV systems. The obtained results lead to the conclusion that the capacity of the PV system may have an impact on the $f_{P,nren}$ indicator.

The frequency distribution (Figure 7) meets a normal Gauss distribution, but it is slightly shifted to the left side. This result shows that the values of $f_{P,nren}$ for C group (capacity is less than 10 (kW)) is bigger 32–43% compared with the A and B groups.

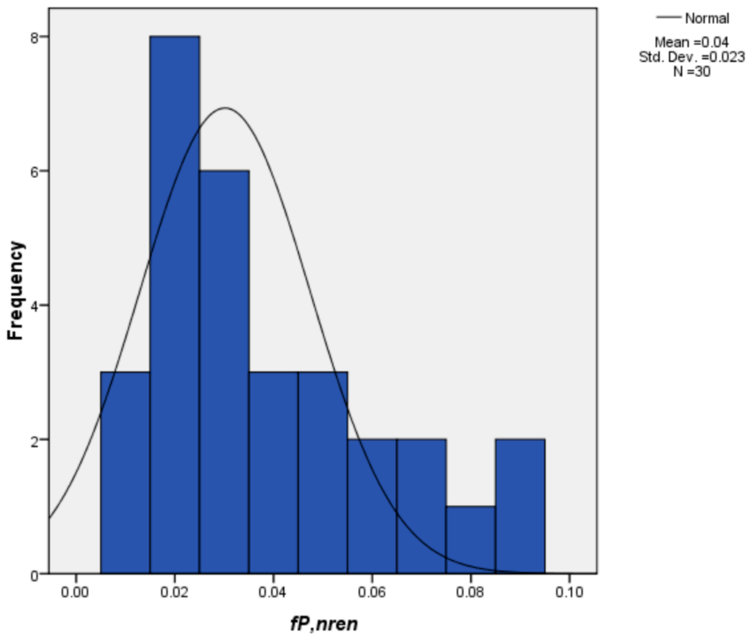

Figure 7. The frequency distribution of the values of the non-renewable energy factor of PV systems.

The result of the primary energy factor calculation is presented in Table 2.

The investigation has shown that the PEF value of the PV systems of group C with less than 10 (kW) of capacity is bigger ($f_{P,tot}$ = 1.065) than that of the PV systems of the A and B groups with more than 10 (kW) of capacity (respectively, $f_{P,tot}$ = 1.021 and 1.028). This difference consists of 32–43%.

4. Discussion

The global problem regarding climate change is related to the excessive usage of fossil fuels and greenhouse gas emissions. Taking into account their negative environmental impact as well as the global temperature rise of below 2 °C [36], the EU designates a lot of attention to energy saving. Due to today's energy trends, it is recommended to reduce the energy consumption of the building sector. Currently, about 3% of Europe's building stock meets the top "A+" energy class, called "Nearly Zero Energy Buildings" (NZEBs). This means that the other 97% of buildings are marked by a low energy performance [37]. National activity in the area of building renovation depends on the Member State, while the average data indicate that only 0.4–1.2% of the stock is retrofitted and modernized every year [38]. Renewable energy, for example, solar energy, can be used in NZEBs to provide a reduction in pollutants from the power generation process [39]. As shown in the literature [40], the application of solar water heaters can result in a 10–15% reduction in energy consumption, and solar heating systems are able to make a 45% energy saving in buildings [40]. All in all, renewable energy sources should undoubtedly be used in modern buildings, and they could be an important contributor to the design and development of NZEBs [41].

The PEF is mentioned in several EU Directives for translating the primary utilization into final energy. For instance, EED [19] or EPBD [18]. The EPBD Directive aims to decrease the primary energy demand for buildings. There are possible several improvements in the building envelope, like the isolation of external walls or the replacement of old windows by more airtight ones, leading to savings in final energy. Then, the PEF is applied to convert these savings into primary energy. The EED is the EU-wide Energy Efficiency target that has been expressed in both primary energy and final energy [2]. During the estimation of Member States' savings in primary energy, the PEF is used for a conversion of the final energy savings into primary energy. It means that savings in the area of electricity can be multiplied by 2.5. However, the analysis of the PEF calculation options for electricity in 2016 [25] showed that the PEF incentivizes savings in electricity over direct fossil savings, as necessary to meet the targets of EEP. Nowadays, a significant renewable generation capacity is added to the electricity system, creating a linkage between the electricity and heat sectors. Such actions could successfully help to meet expectations and tackle challenges; however, the current PEF for electricity can be found as an obstacle during the process of decarbonization in the heating sector.

Currently, Member States have a choice to use their own PEF value according to EED and EPBD. The results of the investigation of the review sources are given in Table 3, which shows that EU countries have provided various PEF values. The national laws of many EU member states governing the construction sector do not include or sometimes do not define the PEF values, so the problem with clear values for defining photovoltaic energy appears. It is crucial to develop consistent and normalized values that could be used for both technical and scientific applications, as well as financial analyses.

Table 3. The PEF values of photovoltaic energy used in the laws of EU countries.

Country	PEF	Total PEF, $f_{P,tot}$	Non-Renewable PEF, $f_{P,nren}$	Renewable PEF, $f_{P,ren}$	Literature Source
Slovak Republic	-	1.00	-	-	[42]
Denmark	2.5 1.8 **	-	-	-	[43]
France	1.00	-	-	-	[44]
Germany	1.00				[45]
Amorphous *	-	1.29	0.27	1.03	
Monocrystalline *	-	1.53	0.47	1.05	
Polycrystalline *	-	1.25	0.23	1.02	
Ireland	2.45	-	-	-	[46]
Hungary	0	-	-	-	[47]
Italy	-	2.17	2.17	-	[48]
Poland	-	1.00	0	1.00	[49]
Slovenia	0.00	-	-	-	[50]
Sweden	-	0.17	-	-	[51]

Note: -not mentioned; * the values apply depending on the type of components that make up the PV system; ** the values are applicable from 2020 onwards.

Thus, the PEF is applied to convert the savings in buildings into the value of primary energy, with regard to the energy efficiency of the products and types of fuels used. The PEF is applied to convert electricity (final energy) into primary energy. Such analysis should us allow to compare the energy damages or savings between different countries. Because the energy savings depend on the locations, climate conditions, political aspects, etc., of different countries, directive [22] provides an evaluation of the PEF, including the national factors. Unfortunately, the analysis of researchers' reports shows that not all the EU-28 countries evaluate the PEF. Maybe the reason for that is a negative approach to PEF. For instance, Firlag and Piasecki [52] state that the use of PEFs to estimate the energy consumption in buildings is often incorrect or results in opposite effects. Authors have analyzed systems with dual fuel boilers that are used for burning both biomass and coal that were found to be very common in some Member States—e.g., Poland. The results of their analysis showed that energy characteristics often did not meet reality, as by not using the proper proportion of coal and biomass and their PEFs in calculations, the real energy consumption and emission of air pollutants such as carbon dioxide were significantly greater than the calculated ones. Thus, the estimated ecological targets were not met in reality.

However, in another opinion presented by Esser and Sensfuss [25], PEF is based on a scientific approach and makes the factor well aligned with the actual of power generation. Authors claim that it also reflects well the EU energy mix and the increasing share of renewable sources in electricity production.

So, Lithuania chose to set the PEF for different renewable energy sources. This study focused on the evaluation of the PEFs of PV systems. The values of the total PEF of the PV systems operated in Lithuania, estimated as the average $f_{P,tot}$ = 1.038, are similar to factors used in Germany and France. However, as presented in Table 1, in some of the EU countries the obtained results for PEF differ significantly—e.g., in Ireland or Denmark. The methodology for PEF determination in the countries mentioned is not very clear, and thus it could be related to the capacity of PV systems. This primary outcome highlights the importance of further research.

Overall, this paper proposes guidelines for PEF determination; however, it is necessary to note that each national case should be carefully analyzed. It is recommended to consider the individual NZEB data, the local climate, and regulations, especially when there is a lack of methodology to determinate the PEF values. Undoubtedly, the proper PEF values are crucial for setting a precise primary energy level. Thus, its appropriate estimation influences energy policymaking analysis, energy consumption efficiency in international and national energy statistics, and environmental impact assessments. Thus, all EU members should define the primary energy in PV systems.

5. Conclusions

The investigation has shown that the total average primary energy factor $f_{P,tot}$ is 1.038. This could depend on the capacity of PV systems. The value of the non-renewable energy factor $f_{P,nren}$ of PV systems which have capacities of less than 10 kW is 0.065; it is 0.028 for PV systems with capacities ranging from 10 to 20 kW, and it is 0.021 for PV systems which have capacities of more than 20 kW. This difference consists of 32–43%. Hence, the total value of the primary energy factor depends on the capacity of PV systems. The study recommends using different values of the non-renewable energy factor $f_{P,nren}$ regarding the capacity of PV systems for the evaluation of the amount of primary energy consumed in NZEB buildings.

In order to achieve the aforementioned goals, all the EU member states must use the same or similar methodology to calculate the primary energy factor of renewable and non-renewable energy sources.

Author Contributions: All the authors contributed equally to this work. All the authors designed the calculations, discussed the results and implications, and commented on the manuscript at all stages. R.T. calculated various primary factor values of non-renewable energy of PV systems of different capacities and interviewed PV system owners/operators. D.A.K. and V.M. analyzed the climate data and prepared the report of electricity transmission system operators. J.Š. wrote the paper. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Basic Science Research Program through the Kaunas Technology University (Lithuania) and the HE Ministry grant WZ/WBiIS/9/2019 at Bialystok University of Technology (Poland).

Conflicts of Interest: The authors declare no conflict of interest.

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