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# Evaluation of Primary Energy from Photovoltaics for a Nearly Zero Energy Building (nZEB): A Case Study in Lithuania †

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**Abstract:** The European Commission has set the target in the Energy Efficiency Directive (EED) to reduce EU primary energy consumption in 2020 by 20%. A crucial aspect of the overall assessment of energy saving measures that affect electricity demand is the primary energy factor that is used for evaluation of primary energy consumption from renewable energy resources in a Nearly Zero Energy Building (nZEB). The analysis of the resources has revealed that energy from photovoltaics is evaluated using different methods. Therefore, this article's aim is to investigate and evaluate the primary energy factor of energy from photovoltaics using the data of produced and consumed energy of 30 photovoltaic (PV) systems operating in Lithuania. Investigation results show that the difference of non-renewable primary energy factor between the PV systems due to capacities is 35%. In addition, the results of the studies show that the average value of the primary energy factor of PV systems in Lithuania is 1.038.

**Keywords:** primary energy; renewable energy; photovoltaic system; energy efficiency; auxiliary energy

## 1. Introduction

Reducing energy consumption of existing buildings and achieving nearly zero energy buildings (NZEBs) are the main focuses of the Energy Efficiency Directive (EED) [1] and of the Energy Performance of Building Directive (EPBD) [2]. Directive (EU) 2018/844 [3] recommends to use renewable energy sources that consist of more than a half of the total energy, and to reduce the amount of non-renewable energy used in energy-efficient buildings. However, the part of energy from a non-renewable energy source cannot be defined because it depends on the additional energy consumed in the conversion device, which normally uses non-renewable energy, such as electrical energy, a common grid or fuel [4].

A primary energy factor, often referred to as a conversion factor, is required to calculate the total energy consumption, including the chain of energy generation based on the final energy consumption data. That means, the primary energy factor is a sum of renewable energy factor $f_{P,ren}$ and non-renewable factor $f_{Pn,ren}$. Renewable energy must account for the major proportion of the energy consumed in a building. According to the standard for building energy performance EN 15603: 2014 [5], the $f_{P,ren}$ is equal to 1. That standard's EN 15603 (CEN, 20081) evaluation goes on defining separate the primary energy factors for renewable and non-renewable energies. The analyzed resources have shown that the assessment of primary energy demand for buildings uses the non-renewable energy factor ($f_{P,nren}$), which is often thought to be 0.0 [6]. However, a few EU countries allow the $f_{P,nren}$ values to be publicly viewed and a range of those values is approximately 2.2 (ranges from 0 to 2.2) [7]. Such investigation did not give sufficient information about the value of the primary energy factor calculation method in individual cases. Nevertheless, many different methodologies are given for the primary energy factor calculation [8,9]. Only with sufficiently accurate data on PV renewable ($f_{P,ren}$) and non-renewable ($f_{P,nren}$) primary factors can the amount of renewable and non-renewable primary energy from PV systems consumed in a building be objectively calculated. Therefore, this article aims to investigate and evaluate the primary energy factor of energy from PV systems with different capacities.

## 2. Methods

Lithuania is in the south-western sub-area of the Atlantic continental zone. 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).

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

Data for the investigation was collected from 30 PV systems operating in Lithuania by interviewing PV systems owners/operators and by analyzing the reports of electricity transmission system operators in the country. 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 total primary energy factor may be calculated by Equation (1) according to regulation of EN 15603:2014 [5].

$$f_{P,tot} = f_{P,nren} + f_{P,ren} \quad (1)$$

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

It is assumed 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 the value of the efficiency of electricity production $\eta_{el}$, and the losses of electricity transportation $e_T$ were evaluated by the calculations. The building normative documents of Lithuania for building electricity consumption calculations provide that $e_T = 0$ and $\eta_{el} = 2.8$. The value of the primary non-renewable energy factor $f_{P,nren}$ produced by PV system is given by the formula (Equation (2)):

$$f_{P,nren} = \frac{E_p \cdot e_T + E_c \cdot \eta_{el}}{E_p + E_c}; \quad (2)$$

where, $E_c$—the amount of consumed energy, kWh/year; $E_p$—the amount of produced energy, kWh/year; $\eta_{el}$—the coefficient of the efficiency of electricity production ($\eta_{el} = 2.8$); $e_T$—the coefficient of the losses of electricity transportation ($e_T = 0$).

The calculation of the value of the primary energy factor of the electricity produced by PV system was done according to the data provided by the monitoring of PV system between the years 2014 and 2018 in Lithuania.

## 3. Results and Discussion

The calculated $f_{P,nren}$ factors of the analyzed PV systems are presented in Figure 1.

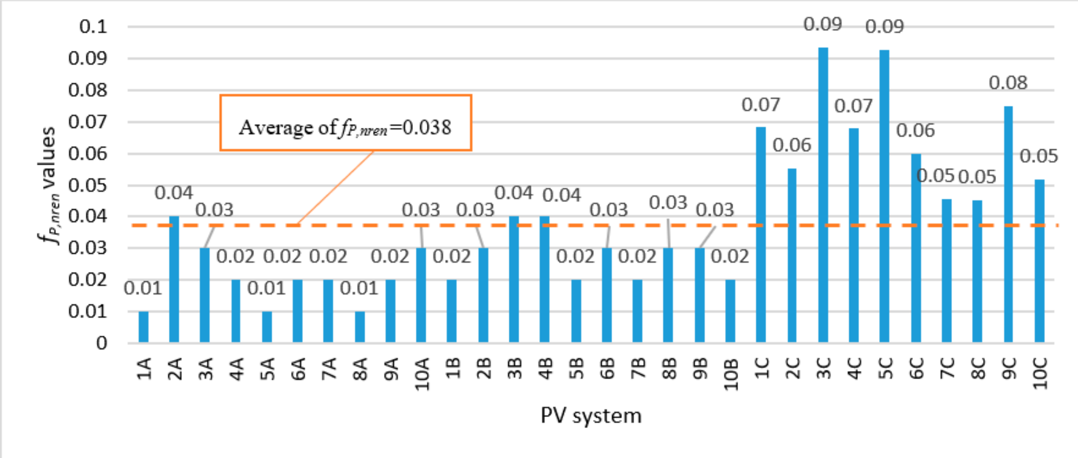


**Figure 1.** Relationship between $f_{Pnren}$ and PV power in PV systems.

The data presented in Figure 1 shows that the average numeric indicator of $f_{P,nren}$ factor in PV systems is 0.038 (the dotted line). The average numerical value of $f_{P,nren}$ indicator for PV systems of A group, where the capacity of PV systems are more than 20 kW equals to 0.021. A similar result was set in B group, where the capacity of PV systems is 20 ÷ 10 (kW)—the average of $f_{P,nren}$ equals to 0.028. However, the average of $f_{P,nren}$ value for C group (capacity is less than 10 kW) reaches 0.065.

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

The result of the primary energy factor calculation is presented in Table 1.

**Table 1.** The result of the 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 investigation has shown that the primary energy factor value of the PV systems of group C with less than 10) kW of capacity is bigger ($f_{P,tot}$ = 1.065) than of the PV systems of A and B groups with more than 10) kW of capacity ($f_{P,tot}$ = 1.021 and 1.028). This difference consists of 32 ÷ 43%. Accordingly, the primary investigation shows that the aspect regarding the capacity of PV systems should be assessed in order to determine the primary energy factor. This primary outcome highlights the importance of needed further research

Overall, this study provides guidelines for the primary energy factor determination; nevertheless, each case should be carefully examined on an individual nearly zero energy building (NZEB) basis and the local climate, especially when there is no exact methodology for determining PEF values. However, primary energy factor is important for setting precise primary energy values, which are used in energy policymaking, defining energy-saving goals or energy consumption efficiency in international and national energy statistics, scenarios, environmental impact assessments, directives and standards. Every European Union member state should define the primary energy in PV systems.

## 4. Conclusions

The investigation has shown that the primary energy factor may depend on the capacity of the PV systems. The value of non-renewable energy factor $f_{P,nren}$ of the PV systems, of which capacities are less than 10 kW, is 0.065 and it is 0.028 of the PV systems with capacities ranging from 10 to 20 kW and 0.021 of the PV systems, with 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.

This study provides guidelines for the primary energy factor determination. All EU countries should examine each case on an individual nearly zero energy building (NZEB) and the local climate. This would help to achieve the goals set forth in the EU energy efficiency and renewable energy directives and regulations.

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

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

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