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Different balancing methods for Net Zero Energy Buildings - Impact of time steps, grid interaction and weighting factors

Monika Hall[a,*], Achim Geissler[a]

[a]*University of Applied Sciences and Arts of Northwestern Switzerland, Institute Energy in Building, St. Jakob-Strasse 84, 4132 Muttenz, Switzerland*

Abstract

Adding large photovoltaic systems to buildings is becoming more and more popular. To date, the self-consumption/grid interaction is not typically part of the energy balance. The choice of symmetric or asymmetric primary energy factors has an impact on the balance. The primary energy factor for import from the grid depends on the chosen type of the power mix in the grid. If this factor is higher/lower than the primary energy factor of the on-site PV-system, a larger/smaller PV system than when using symmetrical factors is required in order to fulfil the NZEB balance.

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Keywords: self-consumption; autarky; grid interaction; energy balance; primary energy; net zeo energy buildung

1. Introduction

The energy balancing of buildings is usually based on aggregated annual values. If the annual PV-yield is as high as the total annual energy demand, the building is called a Net Zero Energy Building (NZEB) [1]. With this approach, the time shift of PV-yield and energy demand is not considered in the energy balance. Fig. 1 shows the annual balance

* Corresponding author. Tel.: +41-61-467-4561
E-mail address: monika.hall@fhnw.ch

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for the autarky and self-consumption rates based on evaluation at different time step resolutions for a small apartment building (monitored values: 15 min). The annual PV-yield is higher than the annual demand. With a monthly or daily time step, the lack of winter PV-yield cannot be compensated with the summer yield. For evaluation at time steps shorter than a daily range, the mismatch of day and night is taken into account. The time steps of 1 min and 1 sec are extrapolated based on [2], [3]. In general, one can summarize the data given in Fig. 1 with "the shorter the time step, the lower the autarky and self-consumption rate". Therefore, it is paramount to know the time step resolution for autarky or self-consumption rates.

Annual and detailed monthly values for two time step resolutions are shown in Fig. 2. It can be seen that the implied autarky rate of the aggregated monthly values is twice as high as the autarky rate found for the 15-min balance. This clearly shows the high impact of the different time steps on the energy balance.

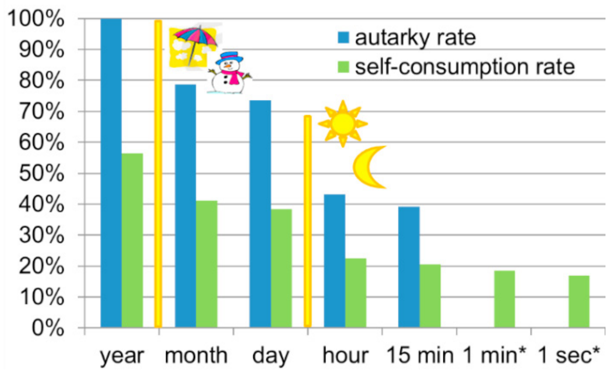

Fig. 1: Annual balance of measured data based on different time steps (building description: [4], 20 kWp, ground source heat pump, mechanical ventilation with heat recovery, Minergie-P, three apartments, without electric vehicle, time span 05/2013-04/2014).

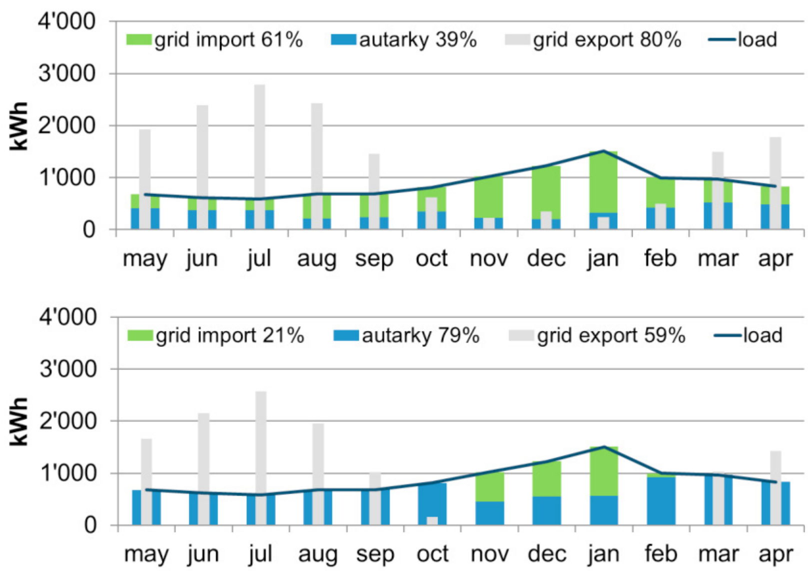

Fig. 2: Annual and monthly values for autarky, grid import and grid export based on 15- min values (top) and aggregated monthly values (bottom), time span 05/2013-04/2014.

Presently, the energy balance is based on aggregated annual values and energy carriers are weighted with primary energy factors or the Swiss national weighting factors. The factors are basically the ratio between primary energy and end-use energy at the gate of the building. This concerns delivered energy from an off-site source like e.g. electricity from the public grid or from an on-site source e.g. electricity from a photovoltaic system on the roof. Although the primary energy factors for an on-/off-site production/supply are different (asymmetric weighting factors) it is common to weight the imported and exported electricity with the same weighting factors (symmetric weighting factors), thus treating the exported electricity as a substitution for electricity from the grid.

In its revised issue dated 2015, SIA 380 [5] adopted "asymmetric primary factors" for the first time. The standard requires using specific values for electricity from on- and off-site sources, which generally differ. It is possible, however, to take a supply contract into account. If such a contract guarantees supply of electricity with a lower primary energy factor than the "standard" Swiss consumer grid value, this lower factor can be used.

The revised guideline SIA 2031:2016 [6] requires a balancing of electricity im- and export with a time step resolution of one hour or shorter to verify the autarky rate. Hereby, asymmetric primary energy weighting factors according SIA 380 or the Swiss national weighting factors [7] are to be used.

The impact of symmetric/asymmetric factors on the NZEB-balance, the design of the PV-system and on grid interaction is shown for an example building in the following.

2. Results

2.1. NZEB balance with symmetric/asymmetric weighting factors

A single family building with 200 m^2 heated area, ground source heat pump (4.3/2.8 [5]) and an annual total demand of 6'100 kWh/a is designed as an NZEB with a 6.9 kWp PV-System on the roof (orientation S, slope: 30°). The amount of self-consumption is 1'320 kWh/a and 4'780 kWh electricity are imported and exported during the year (final energy). Using symmetric weighting factors for the NZEB balance leads to the same amount of primary energy for im- and export (Fig. 3, left hand side). The 6.9 kWp PV-System is sufficient both for the final energy and primary energy NZEB balance. The exported electricity is considered to be a substitute for the power mix in the grid.

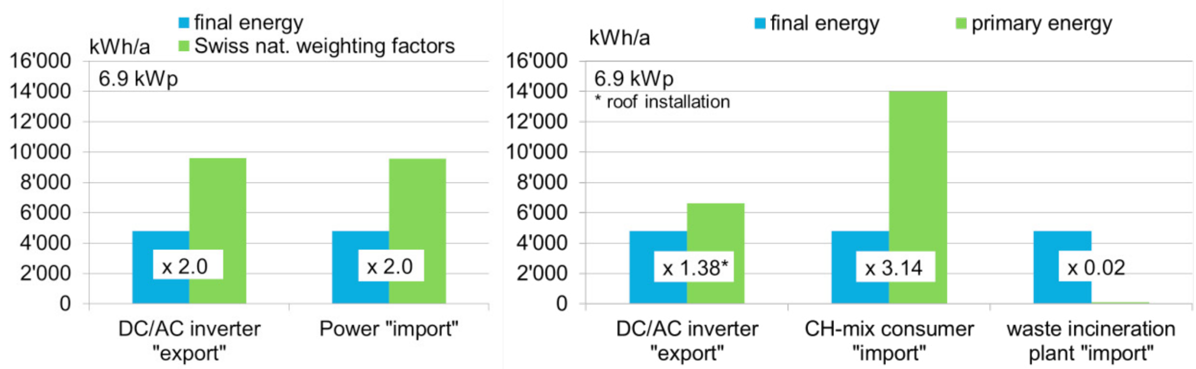

Fig. 3: Different weighting factors: left: symmetric (Swiss national weighting factors), right: asymmetric (SIA 380, primary energy total). Data based on 1 h time step calculations [8].

The right hand side of Fig. 3 shows the impact of the asymmetric weighting factors according to SIA 380 on the balancing. Although the amount of imported and exported electricity is still 4'780 kWh during the year (final energy), the exchange of primary energy differs significantly. The primary energy factor of the DC/AC inverter is approximately half the primary energy factor of the CH-grid "standard mix" and much higher than the primary energy factor for electricity from a waste incinerator plant. The waste incineration plant is chosen in this example because it has the lowest primary energy factor according SIA 380.

Based on three cases, the effects of the asymmetric factors on the primary energy NZEB balance are shown in Fig. 4. The left side shows the case DC/AC inverter/CH-mix without and with a 7 kWh battery. To fulfill the NZEB-balance, a PV-System size of 13.5/11.2 kWp wo/w battery is required, respectively. The self-consumption does not increase proportionally with the PV size, however. In both cases, much more final energy is exported than imported.

The grid-interaction increases. Introducing the battery leads to a reduction in grid-interaction. However, the PV size can only be marginally reduced. Based on dimensioning with asymmetric primary energy factors, the NZEB shows a high annual surplus of PV-yield on the final energy level.

The right side of Fig. 4 shows the case with import of electricity from a waste incinerator plant. Due to the very low primary energy factor, a very small PV-system size of 0.8 kWp is sufficient to fulfill the primary energy NZEB balance. An increase of self-consumption is not necessary. Due to the small PV size, the PV-yield is very low, the self-consumption decreases and the grid import increases. Based on dimensioning with asymmetric primary energy factors, the NZEB misses the zero balance on the final energy level by a huge margin.

Fig. 5 shows a summary of the final energy data for the discussed cases. The impact of the asymmetric weighting factors on the final energy balance, grid interaction and PV size is clearly shown.

Since the beginning of 2017, Minergie requires an "overall balance". For this Minergie indicator, PV-yield can be taken into account. However, this is restrained to the self-consumed yield and an additional 40% of the grid export. Minergie applies the Swiss national weighting factors: electrical demand, PV-yield and power import from the grid are all weighted with the factor 2.0. Even though this is basically a symmetric weighting, the effect of only accepting 40% of the grid export is an indirect asymmetric weighting: 40% of the grid export with weighting factor 2.0 is equivalent to a weighting factor of 0.8 for 100% grid export.

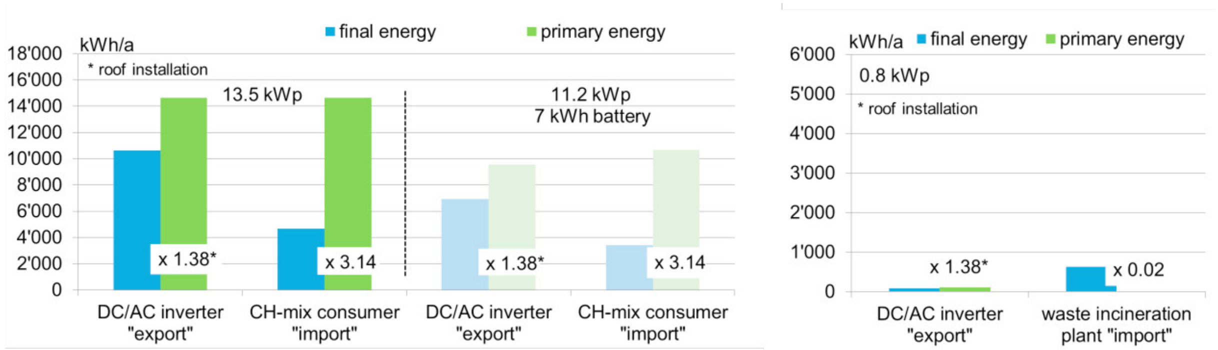

Fig. 4: Impact of different weighting factors on the primary energy NZEB balance: left: DC/AC inverter/CH-mix w/wo battery, right: DC/AC inverter/waste incineration plant. Data based on 1 h time step calculations [8].

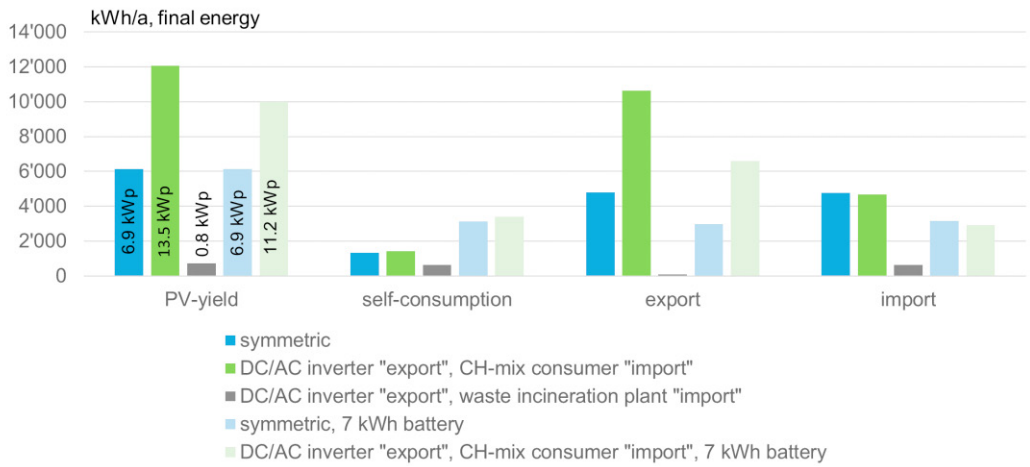

Fig. 5: Resulting final energy data due to the primary energy NZEB balance with symmetric and asymmetric primary energy factors (factors: Fig. 3).

2.2. Self-consumption tool

In order to make the calculation of self-consumption/grid-interaction feasible in the design phase, it is necessary to be able to base the calculations on values which are readily available in this phase without needing to resort to a detailed transient thermal and systems simulation of the building. A simple but sufficient design tool is necessary. There are two such tools available online: "Eigenverbrauchsrechner [9]" and "Unabhängigkeitsrechner [10]". Both are simple, only a few values are necessary to calculate the self-consumption and autarky rates for small residential buildings. Both tools, however, have strong restrictions and are not based on Swiss standards and other guidelines. Therefore, there was a need to develop a new design tool with typical design input values such as heat demand, domestic hot water demand, demand for ventilation, common heating systems, on-site electricity generation, battery size etc. A first version of such a design tool was developed [11]. The design tool "PVopti" is the further development of this first version and is used by Minergie as the application tool for self-consumption [8], [12]. The match of PV-yield and electricity demand can be calculated with a resolution of hourly values. This is a good approximation of time step resolution for the design phase (Fig. 1). Thus, self-consumption and grid interaction can be derived. Fig. 6 shows the results for the example case above calculated with "PVopti". Autarky and self-consumption rate and grid ex-/import are given. These are the basic data for the new energy balance method.

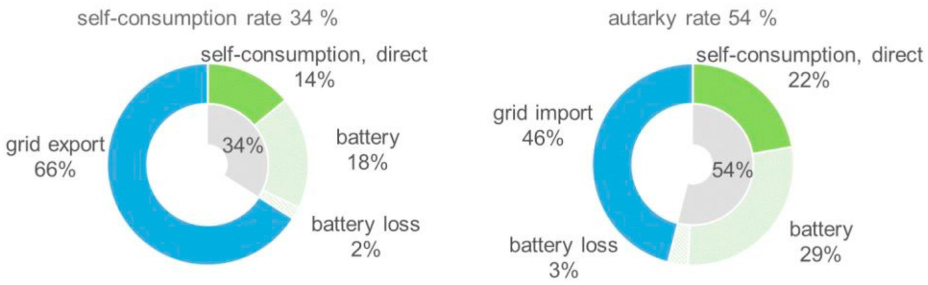

Fig.6: Autarky and self-consumption rate (finale energy), calculated with "PVopti" (6.9 kWp, 7 kWh battery).

3. Discussion

The primary energy balance with asymmetrical factors distorts the balance for final energy. The magnitude of distortion depends on the ratio of the primary energy factors for imported and exported electricity. SIA 380, SIA 2031 and Minergie each handle the balancing differently:

- SIA 380 allows for a power supply contract with a low primary energy factor. Depending on the source of imported electricity, a larger or smaller PV-system is needed in comparison with a balance based on symmetric factors.
- SIA 2031 does not allow for a power supply contract with a low primary energy factor. Therefore, the primary factor for CH-mix is mandatory and larger PV-systems are necessary as compared to a balance with symmetric factors.
- Minergie also does not allow for a power supply contract with a low primary energy factor. However, the eligible PV-yield has no impact on the PV size because the target value of the Minergie indicator already takes the special crediting scheme for PV into account. The idea behind the special PV counting is to support and push the self-consumption.

Balancing with asymmetric primary energy factors according to SIA will often result in larger PV-systems. This is not only a design aspect in regard to the arrangement of the PV-systems on the building (roof, facades) but also a financial aspect for the investor. Larger PV-systems are beneficial to the Swiss Energy Strategy 2050, because more renewable energy will be available. However, they lead to a higher autarky rate and a higher grid interaction which can make upgrading grid infrastructure necessary. The local and seasonal mismatch on the "single building scale" increases and must be addressed.

Efficient small power devices and lighting, well insulated buildings and batteries lead to an increase of the self-consumption and a decrease in size of PV-systems and the grid interaction. However, in terms of the Energy Strategy 2050 efficient buildings are necessary but reducing PV system sizes is not desirable. If the primary energy factor of the imported electricity is larger than the exported electricity the asymmetrical primary energy factors leverage the Energy Strategy.

4. CONCLUSION

It was shown that short balancing time steps lead to lower autarky and self-consumption rates. Newly introduced balancing methods taking self-consumption into account and using asymmetrical primary energy factors have a high impact on the resulting grid interaction. If the primary energy factor of the imported electricity is higher/lower than the exported electricity, the size of the PV-system increases/decreases compared to balancing with symmetric factors. Which option is or should be followed depends to a large degree on the building legislation, energy pricing and likely strategies if energy suppliers. The simple design tool "PVopti" allows calculation of the autarky and self-consumption rates for buildings on an hourly basis in the design phase and also allows calculation of both symmetric and asymmetric weighted energy balances. Minergie is the first to use this tool for their compliance calculations.

The use of asymmetric primary energy factors decouples the primary energy and final energy balances. As shown, this can have a large impact not only on the on-site parameters but also potentially on the grid infrastructure. The discussion about if and how to use asymmetric weighting factors in the energy balance is open.

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