# The impact of different energy balancing methods on net zero energy buildings

Monika Hall, Achim Geissler
Institute of Energy in Buildings, University of Applied Sciences Northwestern Switzerland
Muttenz, Switzerland, monika.hall@fhnw.ch

## Abstract

To date, the building energy balance is typically based on annual values. If the annual PV-yield equals the overall annual energy demand, the building is called a Net Zero Energy Building (NZEB). Of course, this balancing approach does not take into account that PV-yield and electricity energy demand do not necessarily occur at the same time. However, Swiss standards and the building label Minergie have begun to address this issue. The Swiss standard SIA 380:2015, and the Minergie recast 2017 include self-consumption/grid-interaction in the energy balance.

Currently, for the energy balance PV-yield and electricity demand are usually weighted with the same primary energy factor. Minergie 2017 retains this, but SIA 380:2015 features different (asymmetrical) primary energy factors for import from and export to the grid. This necessarily has a large impact on the resulting energy 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 than the primary energy factor of the PV-system, a larger PV system than when using symmetrical factors is required in order to fulfil the NZEB balance.

The impact of balancing method of SIA 380:2015 and Minergie-A on a Net Zero Energy Building are discussed. It is found that the newly introduced definitions for the building energy balance have a large impact on the grid interaction.

*Keywords:* self-consumption, autarky, grid interaction, symmetric/asymmetric primary energy factor, Net Zero Energy Building, energy balancing method, time step resolution

## 1. Introducion

### 1.1 Time steps

Net Zero Energy Buildings (NZEB) are buildings with an aggregated annual PV-yield equal to the aggregated annual energy demand [1]. The time shift between PV-yield and energy demand is not taken into account.

Figure 1 shows the annual balance for the autarky and self-consumption rates for a small apartment building based on monitored values (15 min time steps). The annual balance is given based on different time step resolutions. The aggregated annual PV-yield is much higher than the aggregated annual energy demand, which gives an autarky rate of 100% for the annual balance based on the time step resolution “year”.

The reduced PV-yield during winter cannot be compensated by the summer yield though. This can be seen by the reduced autarky rates for the balance based on monthly or daily time steps. Evaluation at time steps shorter than a day allows for taking the mismatch between day and night 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 Figure 1 with “the shorter the time step, the lower the autarky and self-consumption rate”. It can be seen that the implied autarky rate based on aggregated monthly values is twice as high as the autarky rate found for the 15-min balance.

Figure 2 gives detailed monthly values for autarky and grid im-/export based on a 15 min (top) and aggregated monthly time step basis (bottom). The aggregated monthly time step shows only grid import for November, December and January while the 15 min time step shows grid import every month. This leads to different annual autarky and grid interaction rates. This clearly shows the high impact of the different time steps on the energy balance. Therefore, it is paramount to know the time step resolution used for autarky or self-consumption rates given. For practical reasons, the hourly time step resolution looks like a good compromise for calculation of the self-consumption and autarky rates in the design phase.

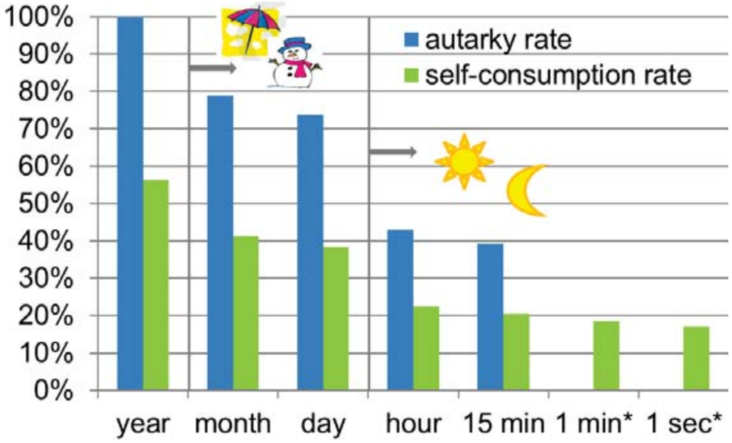


*Figure 1: Annual balance of measured data based on different time steps (20 kWp, ground source heat pump, mechanical ventilation with heat recovery, Minergie-P, three apartments, without electric vehicle, time span 05/2013-04/2014, building description:* [4]*). Values with * are extrapolated.*

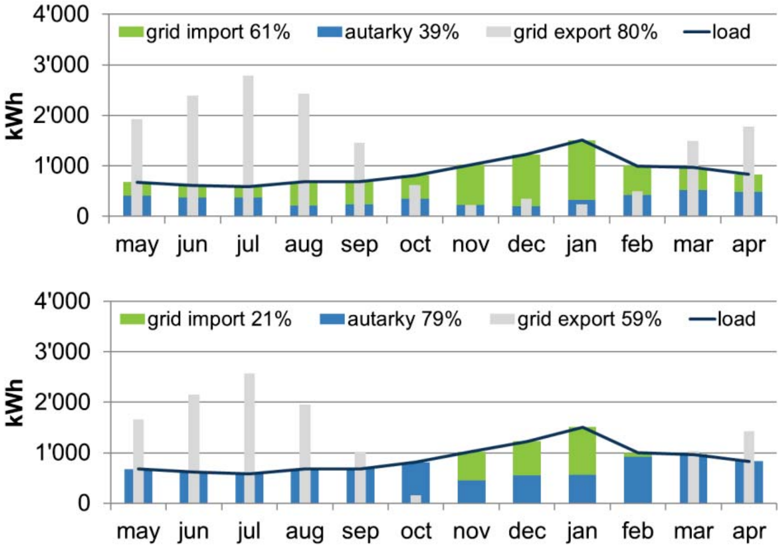


*Figure 2: Monthly values for autarky, grid import and grid export based on 15-min values (top) and aggregated monthly values (bottom), annual statistic, time span 05/2013-04/2014.*

## 1.2 Weighting factors

To date, the energy balance is typically calculated based on energy carriers which are weighted with primary energy factors or the Swiss national weighting factors. Both imported electricity and exported surplus electricity of the building are thereby weighted with the same weighting factors. This is usually called “symmetric primary factors“. The symmetric primary factors basically promote the assumption that the exported electricity is a substitute for the “Swiss consumer mix” in the public grid.

In its revised issue dated 2015, SIA 380 [5] adopted “asymmetric primary factors” for the first time. That is to say, the export of electricity to the grid and import of electricity from the grid are weighted differently. The standard requires using specific factors for electricity from on- and off-site sources, which generally differ. E.g. the electricity exported from a rooftop PV-System has a primary energy factor of 1.38 and imported electricity from the public grid (“Swiss consumer mix”) has a primary energy factor of 3.14. 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 Swiss consumer mix, this lower factor can be used. E.g. electricity from a hydropower plant has a primary energy factor of 1.2.

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 are to be used. However, imported electricity is generally to be weighted with the primary energy factor “Swiss consumer mix”. It is also possible to use the symmetric Swiss national weighting factors [7], though. This is in accordance with the Swiss energy building certificate [8].

## 2. NZEB balance with symmetric/asymmetric weighting factors

The base case is an apartment building with 1’200 $m^2$ heated area, ground source heat pump (4.3/2.8 [5]) and an annual total demand of 39’600 kWh. The building is designed as an NZEB with a 43 kWp PV-System on the roof (orientation S, slope: 30°, Zürich climate). The amount of self-consumption is 12’120 kWh/a and 27’480 kWh/a 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 and the amount of final energy for im- and export is also equal (Figure 3, left hand side). The 43 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. This result is independent of the magnitude of the symmetric weighting factor used.

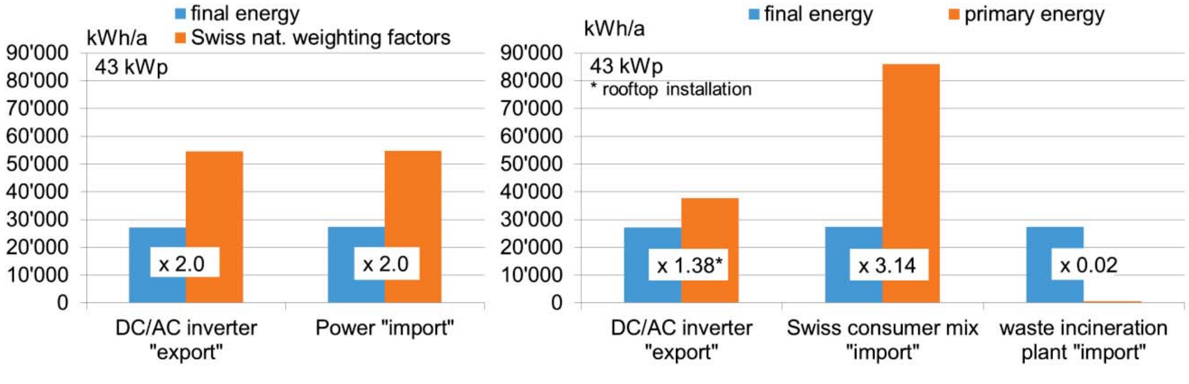


*Figure 3: Different weighting factors: left: symmetric (Swiss national weighting factors), right: asymmetric (SIA 380, primary energy total). Data based on 1 h time step calculations* [9].

The right hand side of Figure 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 27’480 kWh during the year (final energy), the exchange of primary energy differs significantly. The primary energy factor of the DC/AC inverter (1.38) is approximately only half of the primary energy factor “Swiss consumer mix” (3.14) and much higher than the primary energy factor for electricity from a waste incinerator plant (0.02). The waste incinerator plant is chosen in this example because it has the lowest primary energy factor according SIA 380.

Based on these three cases, the effects of the asymmetric factors on the primary energy NZEB balance are shown in Figure 4. The left side shows the case DC/AC inverter/”Swiss consumer mix” without and with a 43 kWh battery. To fulfill the NZEB-balance, a PV-System size of 78/68 kWp wo/w battery is required, respectively. That is to say, in order to be able to fulfil the primary energy NZEB balance a much larger PV size is necessary here as compared to a balance with symmetric weighting factors. Due to the larger PV size, much more final energy is exported than imported. The grid-interaction increases. Introducing the battery leads to a reduction in grid-interaction. Also, the PV size can be reduced because the self-consumption increases with the use of the battery. Based on dimensioning with asymmetric primary energy factors, the NZEB shows a high annual surplus of PV-yield on the final energy level.

The dimensions of the PV sizes are based on a rooftop installation (orientation S, slope: 30°). Depending on the roof area of the apartment building it may not be possible to arrange such a large PV-system on the roof. An extension to the facade could be necessary. As the PV-yield per nominal power installed in the façade is lower than from the roof, the total PV-size would increase. In such a case, it also has to be considered that the primary energy factor for PV-yield from façades is 1.54 as opposed to 1.38 from roof-installations. A PV-yield weighted primary energy factor would need to be used, which would lie between 1.38 and 1.54.

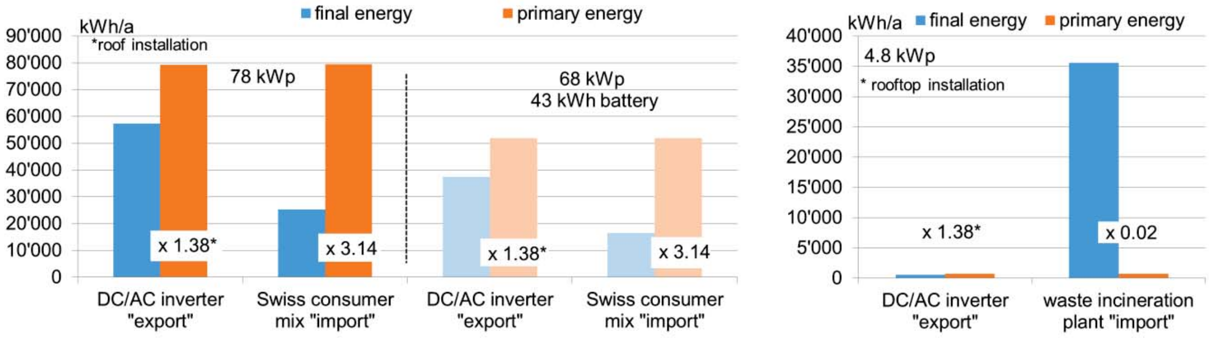


*Figure 4: Impact of different weighting factors on the primary energy NZEB balance: left: DC/AC inverter/“Swiss consumer mix” wo/w battery, right: DC/AC inverter/waste incineration plant. Data based on 1 h time step calculations* [9].

The right side of Figure 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 4.8 kWp is sufficient to fulfil 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, which can be seen in Figure 5 by comparing the grey “import” and “export” columns.

Figure 5 shows a summary of the final energy data for the cases discussed above. 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 certification. 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: electricity demand, PV-yield and 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.

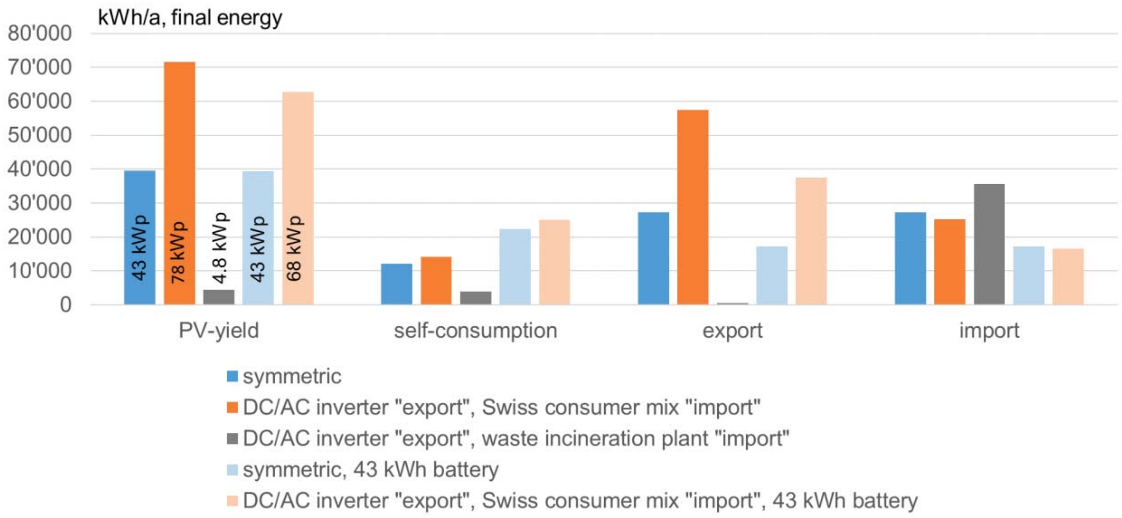


*Figure 5: Resulting final energy data due to the primary energy NZEB balance with symmetric and asymmetric primary energy factors (see Figure 4 for factors).*

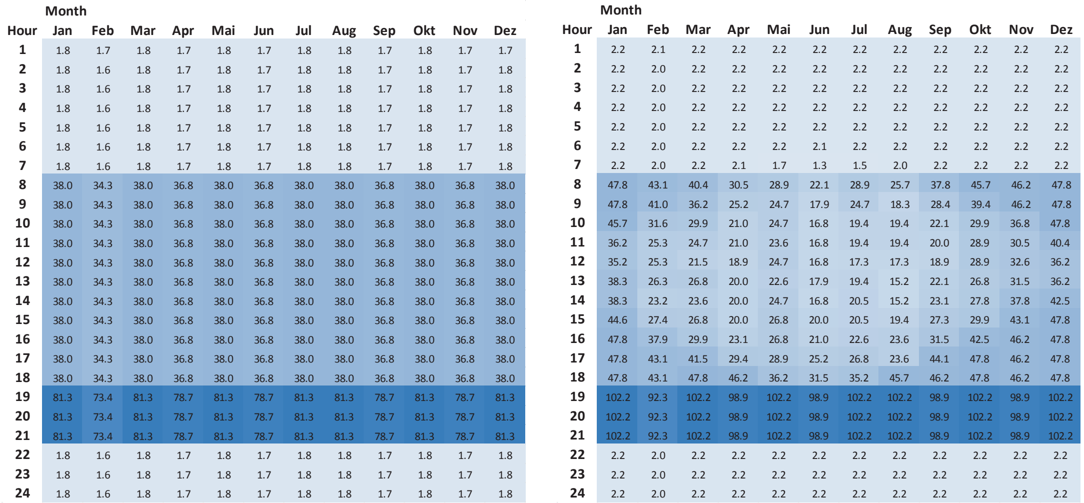
## 3. Self-consumption tool

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 (self-consumption calculator) [10]” and “Unabhängigkeitsrechner (independence calculator) [11]”. 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 Swiss 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 is described in [12]. Once yearly or monthly input data are entered, hourly heat and electricity demand as well as electricity production is calculated by using profiles according to SIA 2024 [13], climate data according SIA 2028 [14] and additional assumptions.

An important example for additional assumptions is the implementation of a daylight criterion for artificial lighting. Lighting profiles according to SIA 2024 do not take seasonal changes in available daylight into account (Figure 6, left side). This approach is improved with an assumption that there is need for artificial lighting when the global irradiation falls below 200 W/m$^2$ only (Figure 6, right side). This assumption gives a better daily and seasonal distribution of the lighting load [12].

The new design tool also can take electricity storage and demand-side management into account. Hourly results are aggregated to yearly or monthly values and displayed as numerical values and graphically as well. The match of PV-yield and electricity demand is calculated with a resolution of hourly values. Thus, self-consumption and grid interaction can be derived.



| | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour | Jan | Feb | Mar | Apr | Mai | Jun | Jul | Aug | Sep | Okt | Nov | Dez |
| 1 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 | 1.8 | 1.7 | 1.8 | 1.7 | 1.7 |
| 2 | 1.8 | 1.6 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 |
| 3 | 1.8 | 1.6 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 |
| 4 | 1.8 | 1.6 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 |
| 5 | 1.8 | 1.6 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 |
| 6 | 1.8 | 1.6 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 |
| 7 | 1.8 | 1.6 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 |
| 8 | 38.0 | 34.3 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 |
| 9 | 38.0 | 34.3 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 |
| 10 | 38.0 | 34.3 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 |
| 11 | 38.0 | 34.3 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 |
| 12 | 38.0 | 34.3 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 |
| 13 | 38.0 | 34.3 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 |
| 14 | 38.0 | 34.3 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 |
| 15 | 38.0 | 34.3 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 |
| 16 | 38.0 | 34.3 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 |
| 17 | 38.0 | 34.3 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 |
| 18 | 38.0 | 34.3 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 | 38.0 | 36.8 | 38.0 | 36.8 | 38.0 |
| 19 | 81.3 | 73.4 | 81.3 | 78.7 | 81.3 | 78.7 | 81.3 | 81.3 | 78.7 | 81.3 | 78.7 | 81.3 |
| 20 | 81.3 | 73.4 | 81.3 | 78.7 | 81.3 | 78.7 | 81.3 | 81.3 | 78.7 | 81.3 | 78.7 | 81.3 |
| 21 | 81.3 | 73.4 | 81.3 | 78.7 | 81.3 | 78.7 | 81.3 | 81.3 | 78.7 | 81.3 | 78.7 | 81.3 |
| 22 | 1.8 | 1.6 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 |
| 23 | 1.8 | 1.6 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 |
| 24 | 1.8 | 1.6 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 |

| | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour | Jan | Feb | Mar | Apr | Mai | Jun | Jul | Aug | Sep | Okt | Nov | Dez |
| 1 | 2.2 | 2.1 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| 2 | 2.2 | 2.0 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| 3 | 2.2 | 2.0 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| 4 | 2.2 | 2.0 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| 5 | 2.2 | 2.0 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| 6 | 2.2 | 2.0 | 2.2 | 2.2 | 2.2 | 2.1 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| 7 | 2.2 | 2.0 | 2.2 | 2.1 | 1.7 | 1.3 | 1.5 | 2.0 | 2.2 | 2.2 | 2.2 | 2.2 |
| 8 | 47.8 | 43.1 | 40.4 | 30.5 | 28.9 | 22.1 | 28.9 | 25.7 | 37.8 | 45.7 | 46.2 | 47.8 |
| 9 | 47.8 | 41.0 | 36.2 | 25.2 | 24.7 | 17.9 | 24.7 | 18.3 | 28.4 | 39.4 | 46.2 | 47.8 |
| 10 | 45.7 | 31.6 | 29.9 | 21.0 | 24.7 | 16.8 | 19.4 | 19.4 | 22.1 | 29.9 | 36.8 | 47.8 |
| 11 | 36.2 | 25.3 | 24.7 | 21.0 | 23.6 | 16.8 | 19.4 | 19.4 | 20.0 | 28.9 | 30.5 | 40.4 |
| 12 | 35.2 | 25.3 | 21.5 | 18.9 | 24.7 | 16.8 | 17.3 | 17.3 | 18.9 | 28.9 | 32.6 | 36.2 |
| 13 | 38.3 | 26.3 | 26.8 | 20.0 | 22.6 | 17.9 | 19.4 | 15.2 | 22.1 | 26.8 | 31.5 | 36.2 |
| 14 | 38.3 | 23.2 | 23.6 | 20.0 | 24.7 | 16.8 | 20.5 | 15.2 | 23.1 | 27.8 | 37.8 | 42.5 |
| 15 | 44.6 | 27.4 | 26.8 | 20.0 | 26.8 | 20.0 | 20.5 | 19.4 | 27.3 | 29.9 | 43.1 | 47.8 |
| 16 | 47.8 | 37.9 | 29.9 | 23.1 | 26.8 | 21.0 | 22.6 | 23.6 | 31.5 | 42.5 | 46.2 | 47.8 |
| 17 | 47.8 | 43.1 | 41.5 | 29.4 | 28.9 | 25.2 | 26.8 | 23.6 | 44.1 | 47.8 | 46.2 | 47.8 |
| 18 | 47.8 | 43.1 | 47.8 | 46.2 | 36.2 | 31.5 | 35.2 | 45.7 | 46.2 | 47.8 | 46.2 | 47.8 |
| 19 | 102.2 | 92.3 | 102.2 | 98.9 | 102.2 | 98.9 | 102.2 | 102.2 | 98.9 | 102.2 | 98.9 | 102.2 |
| 20 | 102.2 | 92.3 | 102.2 | 98.9 | 102.2 | 98.9 | 102.2 | 102.2 | 98.9 | 102.2 | 98.9 | 102.2 |
| 21 | 102.2 | 92.3 | 102.2 | 98.9 | 102.2 | 98.9 | 102.2 | 102.2 | 98.9 | 102.2 | 98.9 | 102.2 |
| 22 | 2.2 | 2.0 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| 23 | 2.2 | 2.0 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| 24 | 2.2 | 2.0 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |

*Figure 6: Electric load (kWh) for artificial lighting according to SIA 2024 (left side) and improved with a criterion for daylight (right)* [15].

The design tool "PVopti" is the public version of the self-consumption design tool based on Swiss standards. It can be used as a stand-alone tool or for Minergie certification application [16]. If "PVopti" is used for the Minergie application, some specific Minergie standard values and input data are required. The results for self-consumption and the amount of electricity fed into the grid must be transferred to the Minergie application form [9], [15]. Figure 7 illustrate the workflow of "PVopti". The comparison of "PVopti" calculations and real measurements shows a good match [15].

Figure 8 shows the results for the example case above when calculated with "PVopti". Autarky and self-consumption rates and grid im-/export are given.

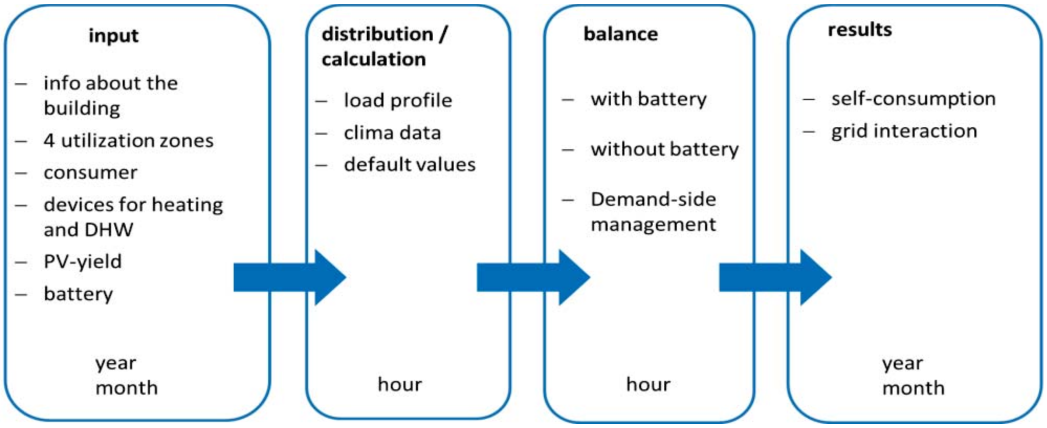


*Figure 7 Workflow of "PVopti"* [15].

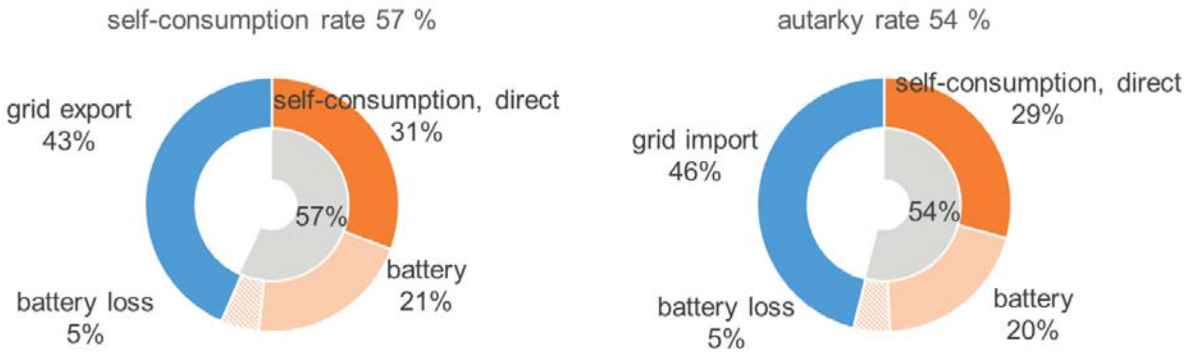


*Figure 8: Autarky and self-consumption rates (finale energy), calculated with "PVopti" (43 kWp, 43 kWh battery).*

## 4. Discussion

The results show that the PV size and the physically relevant exchange with the grid (final energy) is highly effected by the method used when balancing with primary energy factors. 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 lower primary energy factor than the "Swiss consumer mix". Depending on the source of imported electricity, a larger or smaller PV-system is needed in comparison with a balance based on symmetric factors.
- If SIA 2031 is chosen with primary energy factors, no power supply contract with a low primary energy factor is allowed. Therefore, the primary factor "Swiss consumer mix" is mandatory and larger PV-systems are necessary as compared to a balance with symmetric factors. However, if the option of using the symmetric Swiss weighting factors is chosen, the exchange of im- and exported energy matches on the final and primary energy levels.
- 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 a special crediting scheme for PV into account. The idea behind the special PV accounting is to support and push 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.

On the other hand, with a balancing method based on primary energy factors NZEBs could have very small PV systems and are not able to fulfil the final energy balance. They need a lot of final energy from the grid and the upgrading of the grid infrastructure may also be necessary. This case contradicts the Swiss Energy Strategy 2050.

Efficient small power devices and lighting, well insulated buildings and batteries lead to an increase of self-consumption and a decrease in the size of PV-systems and 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 for the exported electricity the asymmetrical primary energy factors leverage the Energy Strategy.

Based on the results shown, the established use of symmetrical weighting factors seems to be the best choice from a practical point of view:

- Final and primary energy balance lead to the same results regarding PV size, imported and exported electricity
- The physically relevant exported electricity immediately substitutes ”Swiss consumer mix” electricity (both final energy).

## 5. Conclusion

It was shown that short balancing time steps lead to lower but more realistic autarky and self-consumption rates. Preferably, time steps equal or lower than an hour are to be used. This takes a diurnal mismatch between supply and demand into account and thus addresses newly introduced balancing methods which include self-consumption evaluation.

The simple design tool “PVopti” allows calculation of the autarky and self-consumption rates on an hourly basis in the design phase. The results can be used for different energy balancing methods according SIA 380 and SIA 2031 or others. Also, “PVopti” is used for Minergie compliance calculations.

The use of asymmetric primary energy factors decouples the primary energy and final energy balances. It is shown that this can have a large impact not only on the PV size but also potentially on the grid infrastructure. If the primary energy factor of the imported electricity is higher/lower than for the exported electricity, the size of the PV-system increases/decreases compared to balancing with symmetric factors. As a possible consequence, “asymmetric NZEBs” could have very small PV systems and would not fulfil the final energy balance by a large margin. The results of this paper indicate that the established approach with symmetrical weighting factors seems to be the best choice for the energy balancing:

- Final and primary energy balance lead to the same results regarding PV size, imported and exported electricity
- The physically relevant exported electricity immediately substitutes ”Swiss consumer mix” electricity (both final energy).

**Acknowledgements**

The results presented in this paper are based on research funded by the Swiss Federal Office of Energy SFOE under contract number BFE SI/501240 as a contribution to IEA Annex 67 *Energy Flexible Buildings*. The paper bases on [15] and [17].

**Nomenclature**

| | |
|---|---|
| Self-consumption | PV electricity generated and simultaneously used to cover own demand, [-] |
| Autarky | Ratio of self-consumption and electricity demand, [%] |
| Swiss consumer mix | electricity mix in the public grid available for the consumer |

## 6. Reference

[1] I. Satori, A. Napolitano, and K. Voss, “Net zero energy buildings: A consistent definition framework,” *Energy Build.*, vol. 48, pp. 220–232, May 2012.

[2] T. Staudacher and S. Eller, “Dezentrale Stromversorgung eines Einfamilienhauses,” *www.ffe.de, BWK*, vol. 4, no. 6, pp. 66–72, 2012.

[3] N. Pflugradt, “Persöhnliche Mitteilung,” Berner Fachhochschule, Burgdorf, 2017.

[4] M. Hall, F. Dorusch, and A. Geissler, “Optimierung des Eigenverbrauchs, der Eigendeckungsrate und der Netzbelastung von einem Mehrfamiliengebäude mit Elektromobilität,” *Bauphysik*, vol. 36, no. 3, pp. 117–129, Jun. 2014.

[5] SIA 380, “Grundlagen für energetische Berechnungen von Gebäuden.” 2015.

[6] Merkblatt SIA 2031, *Energieausweis für Gebäude*. 2016.

[7] EnDK, “Nationale Gewichtungsfaktoren für die Beurteilung der Gebäude.” www.endk.ch, 2017.

[8] GEAK, “Gebäudeenergieausweis der Kantone.” [Online]. Available: www.geak.ch.

[9] Designtool für Autarkie und Eigenverbrauch, “PVopti,” 2017. [Online]. Available: www.minergie.ch.

[10] Basler & Hoffmann AG, “Eigenverbrauchsrechner,” 2015. [Online]. Available: www.eigenverbrauchsrechner.ch. [Accessed: 28-Mar-2017].

[11] Hochschule für Technik und Wirtschaft Berlin, “Unabhängigkeitsrechner.” [Online]. Available: https://pvspeicher.htw-berlin.de/unabhaengigkeitsrechner/. [Accessed: 28-Mar-2017].

[12] M. Hall, B. Burger, and A. Geissler, “Entwicklung eines Planungsinstruments zur Bestimmung der Netzinteraktion von Gebäuden,” in *Brenet 19. Status Seminar, Zürich (CH)*, 2016.

[13] Merkblatt SIA 2024, “Raumnutzungsdaten für die Energie- und Gebäudetechnik.” 2015.

[14] Merkblatt SIA 2028, “Klimadaten für Bauphysik, Energie- und Gebäudetechnik.” 2008.

[15] B. Burger and M. Hall, “PVopti - hourly based energy balance for building design,” in *CISBAT Conference, Lausanne (CH), Energy Procedia*, 2017.

[16] Minergie Schweiz, “Produktreglement zu den Gebäudestandards Minergie/Minergie-P/Minergie-A 2017.2,” 2017.

[17] M. Hall and A. Geissler, “Current and future balancing methods for Net Zero Energy Buildings - impact of time steps, grid-interaction and weighting factors,” in *CISBAT Conference, Lausanne (CH), Energy Procedia*, 2017.