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Two years of experience with a net zero energy balance – analysis of the Swiss MINERGIE-A[®] standard

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Abstract

With the net zero energy balance for heating, domestic hot water, ventilation and auxiliary energy, the Swiss MINERGIE-A Standard is a major step towards standardized, economically feasible net zero energy buildings. Not only the zero energy balance but also the requirement for limited embodied energy is a new challenge for architects and designers. In the two years since the launching of the Standard and the writing of this paper, approx. 240 buildings have been certified or pre certified. The new standard is widely accepted and its challenges are appreciated in the building sector. A cross analysis shows that a wide range of different energy concepts and embodied energy strategies are possible in the scope of the Standard. The wide variety of options is one of the main findings of the rollout of this new zero-balanced standard.

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1. Introduction

The definitions of net, nearly zero and plus energy buildings are being discussed intensely, worldwide. The shared goal of these standards is this: the building must use an on-site renewable energy source. Only the level of balance, i.e. how much of the overall energy consumption should be compensated, varies. Up to now, only a small

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number of buildings are net, nearly zero or plus energy buildings. A database with examples of worldwide net zero energy buildings can be found in [1]. In order to promote the concept and to gather experience with zero-balanced buildings on a larger scale, the Swiss Association MINERGIE implemented a new standard for residential buildings named MINERGIE-A in March 2011 [2]. The Standard prescribes an annual net zero primary energy balance for heating, domestic hot water, ventilation and auxiliary energy. Electricity consumption for appliances and lighting is excluded.

Nomenclature

kWh_{end}	end use energy
kWh_{final}	final energy
kWh_{EPnren}	non-renewable primary energy [3]
kWh_{ECH}	primary energy, weighted with Swiss national weighting factors [4]
m^2	heated floor area (external dimensions)
Wp, kWp	peak PV power
KEV	“kostendeckende Einspeisevergütung”

2. Central requirements of MINERGIE-A

The central requirements for a MINERGIE-A certificate are the following:

- The annual space heating demand must be 10 % or more below the requirements of the national Swiss building regulations [5].
- An annual net zero primary energy balance is required. The energy balance includes space heating, domestic hot water, ventilation and auxiliary electricity (e.g. circulation pumps). The primary energy balance is based on Swiss national weighting factors (E_{CH}) for energy carriers. Provided the energy carrier for space heating and domestic hot water is wood and more than 50% of the demand is covered by solar thermal collectors, a credit of $15 kWh_{ECH}/(m^2 a)$ is given.
- Overall embodied non-renewable primary energy may not exceed $50 kWh_{EPnren}/(m^2 a)$. If the embodied energy does exceed this value, the excess embodied energy can be compensated for by additional electricity generation by means of a photovoltaic (PV) system, however.
- A mechanical ventilation system, energy efficient white goods and energy efficient fixed lighting are required.
- The generation system must be installed on-site (excluding open field PV systems).
- The electricity generated on-site from renewable energy sources may not be sold as “renewable electricity” to a third party.

Operational energy for plug loads and lighting is not included in the net zero energy balance. Nonetheless, MINERGIE-A buildings are appropriate examples to evaluate the step towards net zero energy buildings.

MINERGIE Standards to date were building related, certificates were therefore issued for single buildings, only. Very soon after introducing the MINERGIE-A standard it became clear, however, that only looking at single buildings would restrain acceptance of the new standard too much. Also, it is commonly agreed that meeting the demands of restructuring the energy supply to renewables will make it impossible to consider every building by itself, anyway. MINERGIE therefore has decided to define and accept building-clusters. Such a cluster is an assembly of buildings that are spatially and visually connected. Also, each individual building of the cluster must meet the MINERGIE-A requirements in regard to space heating demand, embodied energy and energy efficient devices. The cluster as a whole must then meet the net zero energy balance. The number of certificates that are issued for such a cluster – only one or one for each individual building – is still being discussed.

In the approximately two and a half years since the launch of the standard and the writing of this paper, 318 applications for a Minergie-A certificate were made, of which 240 buildings have been certified or pre-certified. This paper begins with an analysis of 216 certified or pre-certified buildings (172 single family buildings and 44

apartment buildings), continues with a discussion of the accountability of on-site generated electricity and ends with a summary of the experience gained by practitioners striving to fulfil MINERGIE-A requirements.

3. Analysis of 216 MINERGIE-A buildings

3.1 Energy demand

The analysis for the 216 MINERGIE-A buildings considered is based on design values. The mean value for space heat demand is $22 \pm 7 \text{ kWh}_{\text{final}}/(\text{m}^2 \text{ a})$ that correspond to $64 \pm 12 \%$ of the Swiss building regulation requirement (Fig. 1, left side). The MINERGIE-A buildings to date feature a significantly higher level of thermal insulation than required. On average, they almost meet the requirement of the high insulation Standard MINERGIE-P (which is set at 60 % of the Swiss building regulation requirement for space heat demand). The average value has slightly increased with the number of analyzed buildings (61% 39 build. [6], 61 % 125 build. [7]).

The mean energy demand for heating, domestic hot water, ventilation and auxiliary electricity of all buildings is $17 \pm 7 \text{ kWh}_{\text{final}}/(\text{m}^2 \text{ a})$, leading to a mean primary energy demand of $31 \pm 8 \text{ kWh}_{\text{ECH}}/(\text{m}^2 \text{ a})$ that has to be balanced (Fig. 1, right side). The primary energy demand must be balanced by on-site generation. Nearly all of the buildings achieve the net zero energy balance for heating, domestic hot water, ventilation and auxiliary electricity by on-site electricity generation with the help of a PV system. Only 12 of the considered buildings (approx. 6 %) use the credit for the energy concept with wood and thermal solar collectors. The mean value of electricity generation is $41 \pm 17 \text{ kWh}_{\text{ECH}}/(\text{m}^2 \text{ a})$ and therefore about 33% higher than required.

Table 1 shows average sizing values of the PV installation of the MINERGIE-A buildings. It is found that an equivalent of approx. 10 to 20 % of the heated floor area is necessary to fulfill the net zero energy balance.

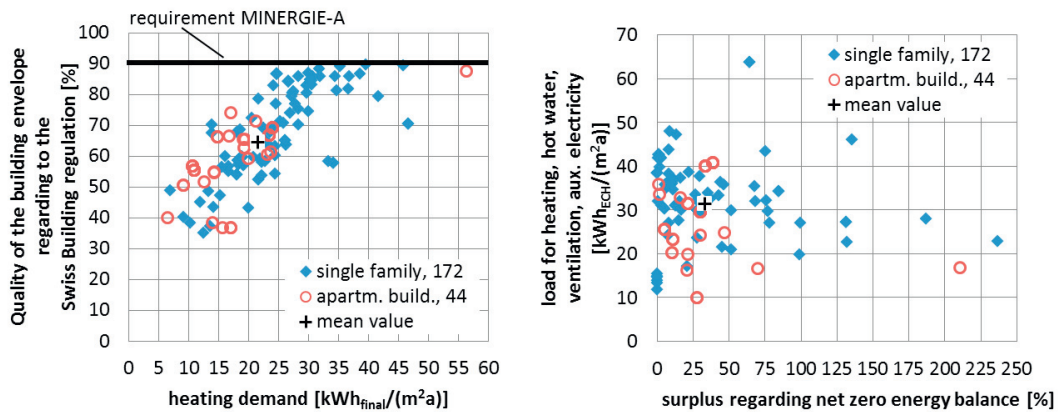


Fig. 1. Level of thermal insulation of the building envelope (left side) and surplus regarding net zero energy balance for 216 MINERGIE-A buildings (right side). The reference area is the heated floor area in all cases.

Table 1. Mean values for primary energy demand, installed PV system peak power and PV system area to meet the MINERGIE-A net zero energy balance (216 buildings).

	all buildings	single family building	apartment building	unit
primary energy / heated floor area	31 ± 8	32 ± 7	30 ± 9	$\text{kWh}_{\text{ECH}}/(\text{m}^2 \text{ a})$
installed peak power	9 ± 10	4.9 ± 2	25 ± 11	kWp
installed peak power / heated floor area*	24 ± 9	24 ± 9	20 ± 10	Wp/m^2
installed PV area / heated floor area**	0.17 ± 0.08	0.17 ± 0.06	0.18 ± 0.11	$\text{m}^2_{\text{PV}}/\text{m}^2$

* similar values were stated in [8], **when PV area unknown: 7 m^2 per kWp is assumed

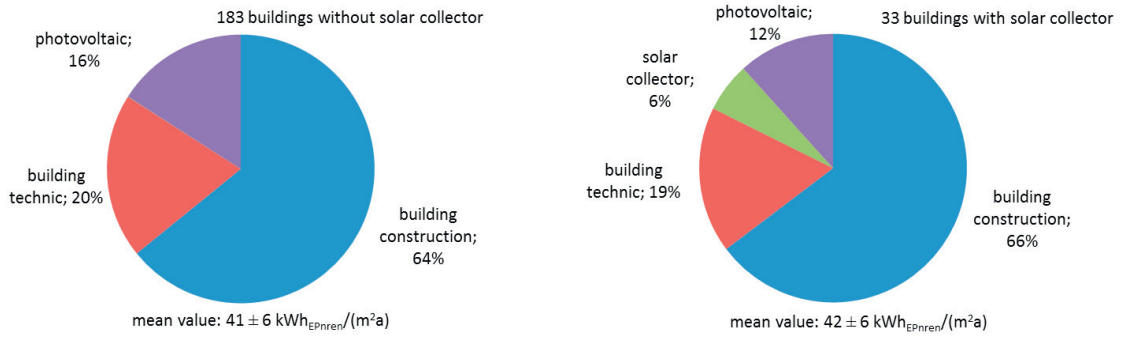


Fig. 2. Distribution of embodied energy for buildings without and with solar collector. Values per heated floor area.

3.2 Embodied energy

The embodied energy is calculated based on a cradle to grave analysis [9]. It includes the superstructure, building envelope, basement, internal walls, space heating, domestic hot water and ventilation systems including the distribution, PV systems and electric installations. Figure 2 shows the distribution of embodied energy for buildings without (the majority) and with thermal solar collectors, respectively. In general, the building construction accounts for about two thirds of the total embodied energy. HVAC installations account for approx. 20% and PV systems and/or thermal solar collectors for the remaining approx. 17 %.

The ratio between thermal building envelope and heated floor areas is a measure for the compactness of a building. A common notion is that a compact building contains less embodied energy as compared to a less compact building. Another common notion in regard to embodied energy is that lightweight (wood based) buildings contain less than heavyweight (concrete/brickwork) buildings. In figure 3 on the left side it is shown that a correlation between embodied energy can neither be found for the building construction nor for the compactness for the buildings considered.

Evaluation of the embodied energy for the considered buildings does not support this notion. It is to add, that lightweight buildings have a massive cellar. Figure 3 (left side) leads to the conclusion that in terms of a requirement for embodied energy, the choice of individual construction materials is more important than the building compactness or the basic building construction type. The mean value of embodied energy of MINEGRIE-A-ECO buildings is about 3 kWh_{EPRen}/(m²a) lesser than of the other MINERGIE-A buildings.

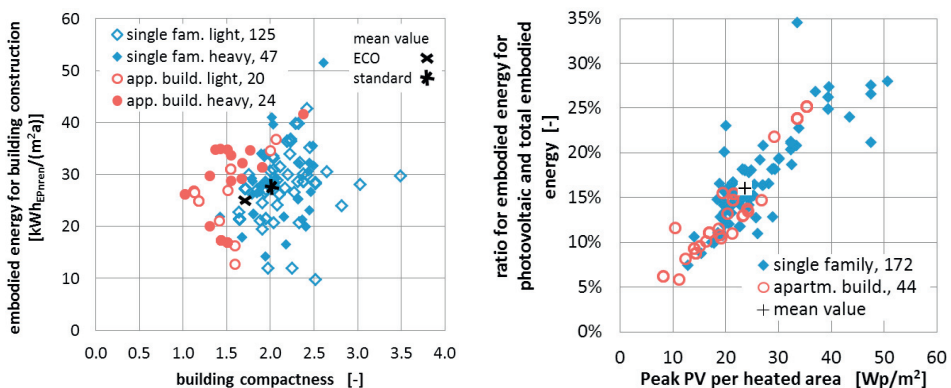


Fig. 3. Embodied energy for building construction vs. building compactness (left side) and percentage of embodied energy due to the PV system vs. installed PV peak power per heated floor area (right side).

Figure 3 (right side) shows the embodied energy percentage of the PV system in regard to the total embodied energy versus peak PV per heated area. On average, the PV system accounts for approx. $16 \pm 4 \%$ of the total embodied energy. In other words, the PV system has a quite significant impact on the total embodied energy. The buildings show a wide range of distribution for installed peak power / heated floor area. The mean value is $24 \pm 9 \text{ Wp/m}^2$ (Table 1).

3.3 Heat generation plants

Table 2 summarizes the systems used for space heating and domestic hot water. The most common system is an electrically driven compression heat pump. This is used for heating in 89% and for domestic hot water in 84 % of the buildings. Nearly 20 % of the buildings use a complementary system for heating, whereas approx. two thirds of the buildings use a complementary system for domestic hot water. Solar thermal collectors as primary system are used for domestic hot water in most cases. Wood and pellet systems are mainly used in single family buildings.

Table 2. Distribution of system types used for space heating and domestic hot water (216 buildings).

	Single family building (172)					Apartment building (44)				
	heating		domestic hot water			heating		dhw		
	1 ^{sd}	2 nd	1 ^{sd}	2 nd	3 rd	1 ^{sd}	2 nd	1 ^{sd}	2 nd	3 rd
Air / water heat pump	58	-	57	3	-	1	-	2	-	-
Brine / water heat pump	94	-	88	6	-	38	-	33	4-	-
Ground water heat pump	1	-	1	-	-	1	-	-	1	-
Pellet system	6	2	-	8	-	-	-	-	-	-
Wood system	8	3	1	7	-	1	1	-	2	-
Thermal solar collector	4	13	25	1	-	1	3	7	1	-
District heating	1	-	-	1	-	2	-	2	-	-
Electric boilers	-	15 ¹⁾	-	96 ²⁾	1 ²⁾	-	1 ¹⁾	-	8 ²⁾	-
total	172	33	172	122	1	44	5	44	16	-

¹⁾ ~1-5% of demand, ²⁾ ~5-10% of demand

4. Balancing options

4.1 General

As the balance is mainly based on electricity generated by PV systems, the balancing options will be only discussed in regard to electricity generated by PV systems. Basically of course, the discussion could be extended to further generating systems or energy carriers. The following has proven to be a very important question in this regard:

What are the guiding principles for the decision if a given generation system can be taken into account for the energy balance?

The corresponding MINERGIE-A requirements (e) and (f) given above sound straightforward at first. But, experience has shown that these requirements can raise quite a lot of questions, which must be considered. According to (e) taking renewable electricity generated by off-site systems into account for the energy balance is not permitted. I.e. the ownership of a windmill only one km away or buying “green” electricity from the grid cannot be taken into account. This strong focus on on-site generation was introduced to facilitate reduction of energy consumption.

The requirement (f) is to ensure that electricity generated from renewable energy sources is only used/balanced once which leads to the so-called ‘ecological balance’.

4.2 Energy balance vs. ecological balance

Two basic balancing methods are being used to date:

- The ‘pure’ energy balancing method – the same amount of electricity must be generated by renewable energy on-site as overall energy used by the building according to the agreed upon balancing boundaries.
- The ‘ecological balance’ – this is based on the trade of guarantees of (renewable) origin for the amount of energy used during the year. Such a guarantee of origin states how and where a given kilowatt-hour was generated. These guarantees of origin are tradable permits. This de-couples the book keeping of such guarantees of origin from the actual source of any given kilowatt-hour taken from the grid at any given time. The additional book keeping of the sources and sinks of electricity ensures that each kilowatt-hour generated by a renewable source is “used” only once.

As given in (f), MINERGIE-A does not accept selling of the electricity generated on-site from renewable energy sources e.g. to a solar stock market. This is due to the fact that the third party buying the corresponding guarantees of origin would “use” the renewably generated electricity the second time – the first usage being to balance the energy demand of the building.

For the same reason, MINERGIE-A does not accept selling of the generated electricity to the special Swiss fund for renewable energy (KEV). This Swiss fund is financed by a premium on electricity in Switzerland and in turn financially supports the installation of renewable energy sources. This electricity increases the renewable fraction of the public grid and would thus also be used twice.

For a MINERGIE-A certificate it is necessary to fulfill both the “energy balance” and the “ecological balance”.

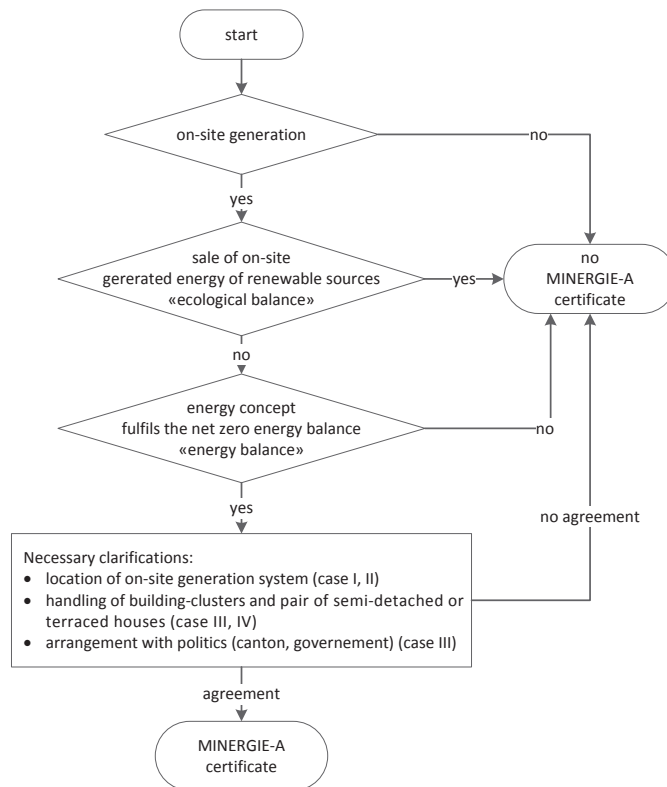


Fig. 4. Steps with tracking the “use” of solar energy regarding the net zero energy balance to reach a MINERGIE-A certificate.



Fig. 5. On-site generation (pictures [2]).

4.3 Balancing and decision procedure

Figure 4 shows the basic decision procedure involved in evaluating the energy balance eligibility for a MINERGIE-A certificate. First, the two basic principles given above are checked for. If both are basically adhered to and the energy balance is zero, a detailed clarification has often proved necessary, nonetheless. Four case studies based on current certification procedures are given below to highlight some of the possible problems involved.

4.4 Case studies

I MINERGIE accepts locations as on-site if these are not located on the actual building, however are located on an adjacent building which functionally belongs to the building being certified. The decision is made individually for each request. Examples are carports, garden walls or barns. So, basically MINERGIE leaves quite a bit of leeway for the “on-site” decision for single buildings (Fig.).

II On-site generation can, of course, lead to serious problems for larger / high rise buildings – these usually have less available area per heated floor area that can be used for the installation of PV systems. If such a building is not part of a cluster as defined by MINERGIE it will not be eligible for a MINERGIE-A certificate.

III Of the 216 MINERGIE-A buildings discussed above, 68 single-family terraced houses and five apartment buildings form a cluster that complies with the definition given above. MINERGIE issued a certificate for each building without referencing the cluster on these certificates. However, additional funding by the Swiss cantons for MINERGIE-A buildings is basically only available for single buildings that comply with the net zero energy balance by themselves. The canton does not accept a certificate one by one for the funding, due to the missing building related net zero energy balance. Therefore, a special solution between MINERGIE and the canton concerned is being negotiated: The whole cluster is to be grouped into seven sub-clusters, each of which receives a MINERGIE-A certificate that includes reference to the sub-cluster. This case shows that politics can have an impact on the discussion of appropriate accounting and certification procedures for net zero energy balances.

IV In the case of row houses the location of the PV system is no problem even if there is no individual installation for each building. Based on the standpoint that such buildings could be viewed as being one building MINERGIE and the cantons generally accept these cases.

4.5 Discussion

It proved necessary to solve each of the above (and many other) cases individually. This of course involved discussions within the MINERGIE Association but in some cases also between MINERGIE and – due to funding programs for energy efficient buildings and PV systems – the canton involved and/or the

Swiss government as well. This interaction with politics was not foreseen during the development of the standard.

The basic idea of not ‘using’ solar energy twice, that means fulfilling the “ecological balance”, is important. However, the implementation of an appropriate system which enables enforcing this idea for a building standard has proved nearly impossible, to date. Using the ‘pure’ energy balancing method would greatly simplify the definition of such a building standard, of course. Initiating the discussion on how to best solve the balancing problem has been an important side effect by the introduction of MINERGIE-A. Defining clear guidelines in order to be able to avoid ‘using’ renewables twice is an important task for the coming years. If, in the future, grid electricity is based solely on renewable energy sources, however, the problem dissolves.

A MINERGIE certificate is based on design values and self-declarations. Only about 10% of the applications are verified on-site. In general, the owner of the certificate is obliged to report any energy related changes. MINERGIE does not have the capacity to actively check on any changes a building owner may undertake. Moreover, contracts can be changed in the future and it is not possible for MINERGIE to track such changes, either.

5. Developments of MINERGIE-A

5.1 General findings

Architects and designers accept the standard. Both appreciate the challenge of achieving the net zero energy balance whilst retaining enough flexibility in design issues. Being obliged to keep an eye on the embodied energy is also welcomed; it is accepted that this issue is becoming more and more important in regard to overall optimization of the energy demand and sustainability of buildings. The analysis of embodied energy for the certified buildings shows that the requirement could be set to a lower value. The same result was obtained from the analysis of the add-on MINERGIE Standard “ECO”, which focusses on sustainability, comfort and healthy items. A recast of the MINERGIE-A standard may therefore include a reduction of the embodied energy target value in the near future.

Fig. 4 shows the numbers of applications per month, the total since march 2011 and some certification details. The mean value of monthly applications is 11. The peak in December 2011 is a result of the application for the building cluster mentioned above. The most buildings are pre-certified (67%). The definitive certificate is only issued when the design values are accepted within MINERGIE and the building has been built as designed. The MINERGIE-A certificate can be combined with other MINERGIE certificates.

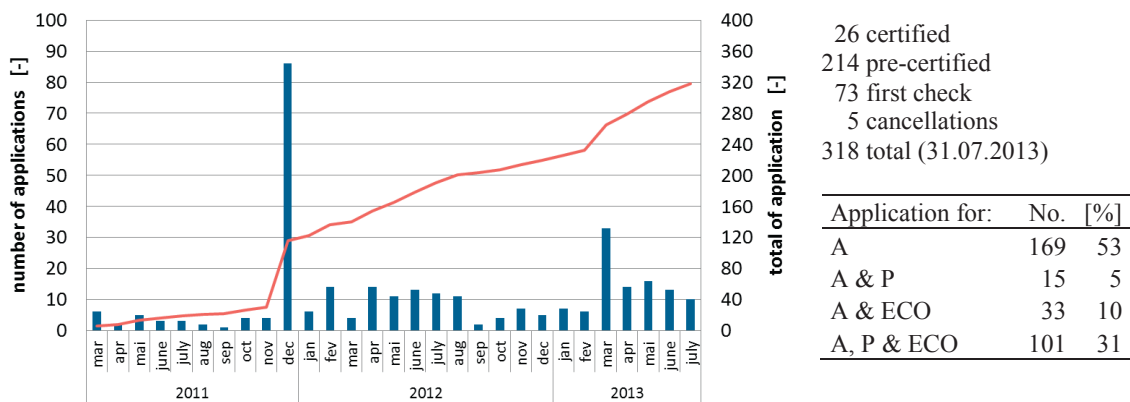


Fig. 4. Development of application numbers for a MINERGIE-A certificate.

5.2 Extension of the MINERGIE-A standard

Enquiries from architects and designers concerning the availability of a MINERGIE-A standard for other types of buildings – especially of course office buildings – have increased. Therefore, a MINERGIE-A definition applicable for office buildings is under development.

Also due to market demand, the MINERGIE-A Standard was extended from new to refurbished residential buildings in January 2013. The requirement of the net zero energy balance for refurbished buildings is the same as for new buildings. There is no special requirement for the space heating demand (the Swiss national requirement is 125 % of that for a new building). This gives designers a high freedom of choice. The embodied energy must only be calculated when MINERGIE expects the new building parts/materials to exceed the requirement of $50 \text{ kWh}_{\text{EPnren}}/(\text{m}^2 \text{ a})$. The embodied energy of existing building materials is set to zero. For eligibility for the MINERGIE-A refurbishment certificate, the construction year must be prior to the year 2000. Five refurbished MINERGIE-A single family buildings exist at the time of writing of this paper.

5.3 Grid interaction – the new challenge

MINERGIE-A buildings are connected to the grid. Nearly every building has a PV system and interacts with the grid, basically using the grid as storage. The net zero energy balance is based on an annual balance. MINERGIE-A does not in any way rate the time shift between demand and generation or the intensity of transient grid interaction. However, MINERGIE is contemplating adding a requirement regarding the load match between demand and generation. This requirement will include plug loads and lighting. A building with an annual overall net zero energy balance typically fulfills a monthly balance for about 70-80 % of the time and an hourly balance for about 30-40 % of the time [10]. MINERGIE is discussing a monthly balance and the use of asymmetric primary energy factors. That means, the import and export of energy is weighted with a different primary energy factor.

Fig. 5 shows the monthly consumption data of an apartment building and PV generation with a 20 kWp PV. To cover different energy balances, different PV sizes are considered. For a MINERGIE-A balance a PV with approx. 5 kWp is necessary, the balance of a net zero energy building (Net ZEB) requires a PV with around 12 kWp. The surplus in summertime increases with the size of the PV. The balance of Minergie-A shows the highest monthly percentage for self-consumption (Table 3).

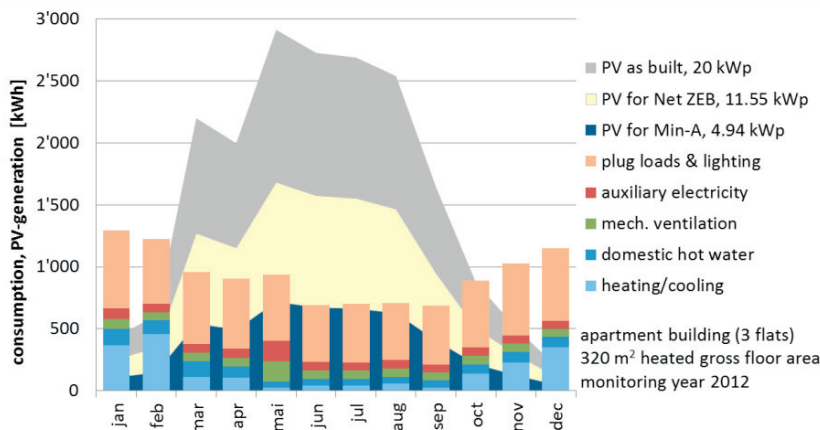


Table 3. Monthly self-consumption (load match index [11]).

PV kWp	Balance for	
	Min-A	Net ZEB
5 ^x	70 %	49 %
12 ^{xx}	81 %	70 %
20	91 %	79 %

^x required for MINERGIE-A balance
^{xx} required for Net ZEB balance

Fig. 5. Monthly grid interaction of different energy buildings standards.

6. Conclusion

The MINERGIE-A Standard is generally accepted in Switzerland. The net zero energy balance for heating, domestic hot water, ventilation and auxiliary electricity is feasible for new and refurbished residential buildings. The typical MINERGIE-A building is well insulated and features a heat pump and a PV system. The analysis of 216 new buildings shows that the mean value of the heating demand is clearly below the requirement of the standard. Also, the mean value of embodied energy found is below the requirement of the standard.

It turns out that fulfilling the net zero energy balance is not the decisive issue. The decision if the energy used for balancing is actually eligible has proven to be more complicated. Many cases need to be solved individually by MINERGIE and also in accordance with the cantons and the Swiss government. This makes certification difficult to handle. The definition of clear guidelines with which ‘using’ renewables twice can be avoided is an important task for the coming years. The distinction between “energy balance” and “ecological balance” is not only a major item for MINERGIE-A, but should be considered and solved for all building standards based on demand/generation balances like nearly zero, net zero and plus energy buildings.

The net zero energy balance for single buildings-only restrains the possibilities. The extension to building clusters is essential.

Grid interaction of buildings with on-site electricity generation will become an increasingly important topic with the increase in numbers of such buildings. Extending the MINERGIE-A Standard with requirements which take this aspect into account are being discussed, therefore.

The experience gained with realizing MINERGIE-A buildings gave important feedback on the pitfalls of implementation of a high performance Standard for new buildings. We expect similar deep insights for refurbishments in the coming months.

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