Accounting for electricity generation for a net zero energy balance – experience gained with MINERGIE-A®

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ABSTRACT: The worldwide discussion concerning energy saving and the reduction of greenhouse gases in the building sector has led to low, nearly zero or net zero energy buildings. The first available Building Standard defining such a zero-balanced type of building is the MINERGIE-A standard for dwellings defined by the Swiss Association MINERGIE. It was implemented in March 2011. This standard prescribes an annual net zero primary energy balance for heating, domestic hot water, ventilation and auxiliary electricity. Electricity consumption for appliances and lighting is excluded. After two years, almost 200 MINERGIE-A buildings are certified or pre-certified. A cross analysis shows that a wide range of different energy concepts are possible in the scope of the label. Achieving the zero energy balance in itself has turned out not to be the problem. Any electricity generated on-site which is to be taken into account in the balance may not be sold to a solar stock market or be made available as 'bulk renewable' in any other way. These restrictions are based on the fact that electricity generated from renewable energy should only be accounted for as 'renewable electricity' once. Defining and applying appropriate rules proved daunting.
Keywords: net zero energy building, net zero energy balance, embodied energy, electricity generation, MINERGIE-A

INTRODUCTION

The Swiss Association MINERGIE is a trailblazer in energy efficient buildings. The association was founded in 1998 and has since then driven the development of increasing the comfort of the indoor environment while reducing energy consumption in buildings. The Standards 'MINERGIE' and in particular 'MINERGIE-P' are focused on the reduction of heat demand. This results in well insulated buildings with a mechanical ventilation system. 'MINERGIE-A' is the newest MINERGIE standard for residential buildings and was implemented in March 2011 [1]. The development of MINERGIE-A goes in line with the worldwide definition and development of standards for nearly and net zero energy buildings [2, 3]. MINERGIE was the first organisation to define and implement an applicable Standard requiring a net zero energy balance. The central requirements for a MINERGIE-A certificate are the following

(a) The annual space heating demand must be 10 % or more below the requirements of the national Swiss building regulations [4].
(b) 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 (ECH) [5] 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.
(c) 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.
(d) A mechanical ventilation system, energy efficient white goods and energy efficient fixed lighting are required.
(e) The generation system must be installed on-site (excluding open field PV systems).
(f) 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 looking at single buildings only 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 years since the launch of the standard, 140 single family buildings and 36 apartment buildings have been certified or pre-certified. This paper begins with an analysis of these 176 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.

ANALYSIS OF 176 MINERGIE-A BUILDINGS

Energy Demand

The analysis for the 176 MINERGIE-A buildings considered is based on design values. The mean value for space heat demand is 20 ± 6 $kWh_{end}/(m^2\ a)$ that correspond to 63 ± 11 % of the Swiss building regulation requirement (Fig. 1). The built MINERGIE-A buildings to date feature a significantly higher level of thermal insulation than required. On average, they almost meet the requirement of MINERGIE-P (which is set at 60 % of the Swiss building regulation requirement for space heat demand).

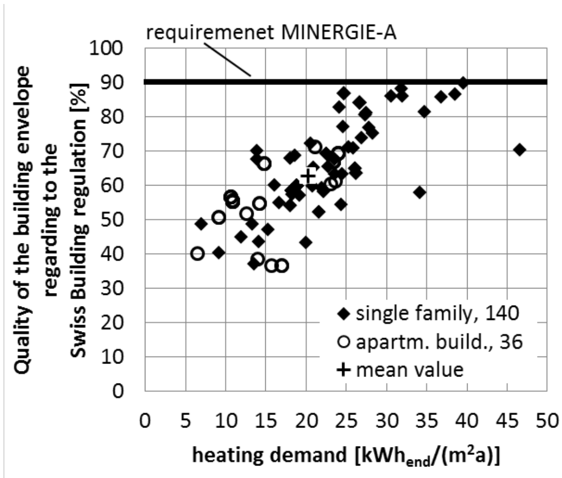

Figure 1: Level of thermal insulation of the building envelope for 176 MINERGIE-A buildings expressed in percentage of space heating demand relative to Swiss building standard requirements (design values).

The mean energy demand for heating, domestic hot water, ventilation and auxiliary electricity of all buildings is 17 ± 6 $kWh_{final}/(m^2\ a)$, leading to a mean primary energy demand of 31 ± 7 $kWh_{ECH}/(m^2\ a)$. 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 seven of the considered buildings (4 %) use the credit for the energy concept with wood and thermal solar collectors. Figure 2 shows that the mean value of electricity generation is 40 ± 12 $kWh_{ECH}/(m^2\ a)$ and therefor about 30% higher than required.

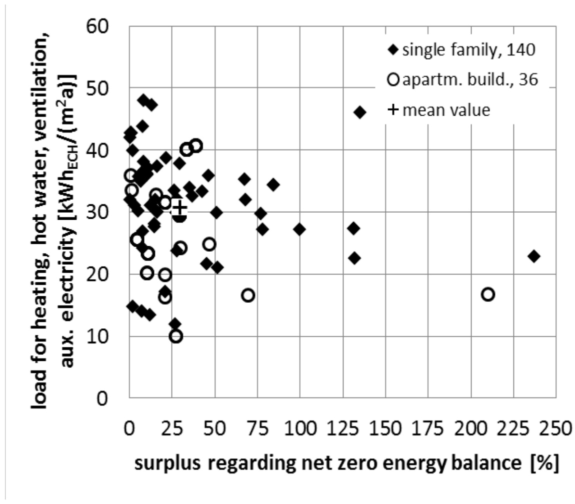

Figure 2: Net zero energy balance for 176 MINERGIE-A buildings (design values).

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 fulfil the net zero energy balance.

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 (176 buildings).

	all buil-dings	single family building	apartment building	unit
prim. energ./ heated floor area	31 ± 7	31 ± 7	29 ± 9	$kWh_{ECH}/(m^2a)$
installed peak power	9 ± 10	4.4 ± 2	25 ± 11	kWp
installed peak power / heated floor area	23 ± 6	23 ± 5	20 ± 9	Wp/m^2
installed PV area / heated floor area*	0.17 ± 0.07	.16 ± 0.05	0.18 ± 0.12	m^2_{PV}/m^2

*when PV area unknown: 7 m^2 per kWp is assumed

Embodied energy

The embodied energy is calculated based on a cradle to grave analysis [6]. 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. Figures 3 and 4 show 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 %.

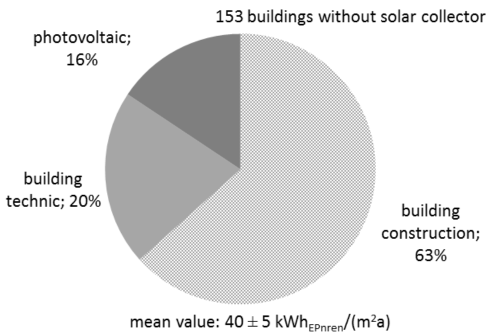

Figure 3: Distribution of embodied energy for buildings without solar collector (153 buildings).

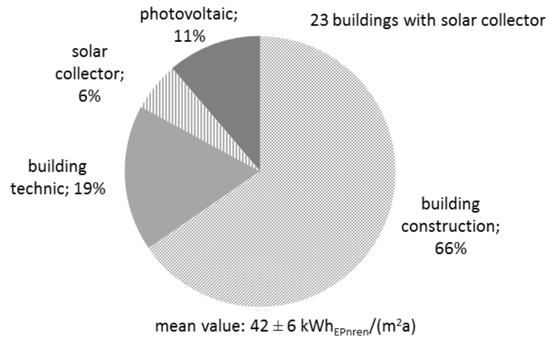

Figure 4: Distribution of embodied energy for buildings with solar collector (23 buildings).

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. In figure 5 it is shown that no correlation between embodied energy for the building construction and the compactness is found for the buildings considered. Another common notion in regard to embodied energy is that lightweight (wood based) buildings contain less than heavyweight (concrete/brickwork) buildings.
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 5 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.

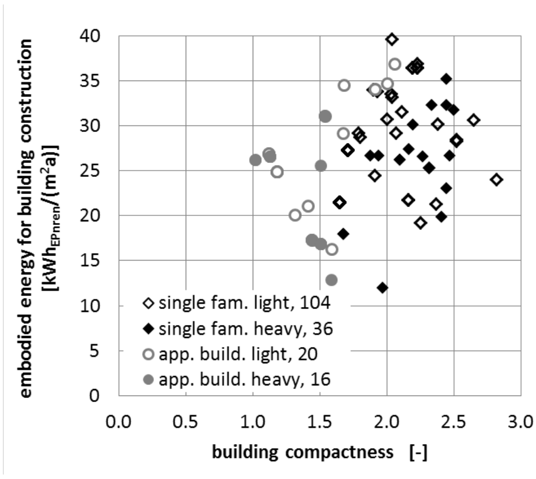

Figure 5: Embodied energy for building construction vs. building compactness.

Figure 6 shows the embodied energy percentage of the PV system. On average, the PV system accounts for approx. 16 ± 4% of the total embodied energy. In other words, the PV system has a quite significant impact on the total embodied energy.

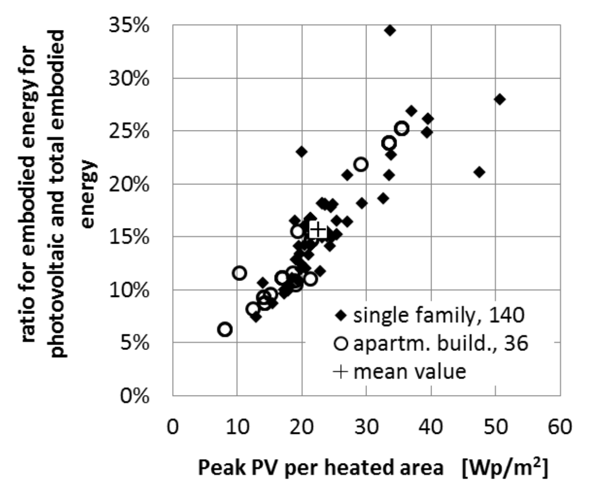

Figure 6: Percentage of embodied energy due to the PV system vs. installed PV peak power per heated floor area.

Heat generation plants

Table 2 summarises 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 91% and for domestic hot water in 85 % of the buildings. A total of 15% 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 only used in single family buildings.

Table 2: Distribution of system types used for space heating and domestic hot water (176 buildings).

system	heating		domestic hot water	
	1st	2nd	1st	2nd
heat pump	160	0	151	10
wood/pellet	10	5	0	13
solar th. collector	4	11	23	1
district heating	2	0	2	0
Electricity[1)]	0	10[2)]	0	93[3)]
total	176	26	176	117

[1)] Electric boilers, [2)] ~1-5% of demand, [3)] ~5-10% of demand

BALANCING OPTIONS

General

For practical purposes, in this section we will focus on electricity generated by PV systems for the energy balance, only. A very important question has arisen in this context:

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

The corresponding 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 is 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'.

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 public grid and would thus also be used twice.

Balancing and decision procedure

Figure 7 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.

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.

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.

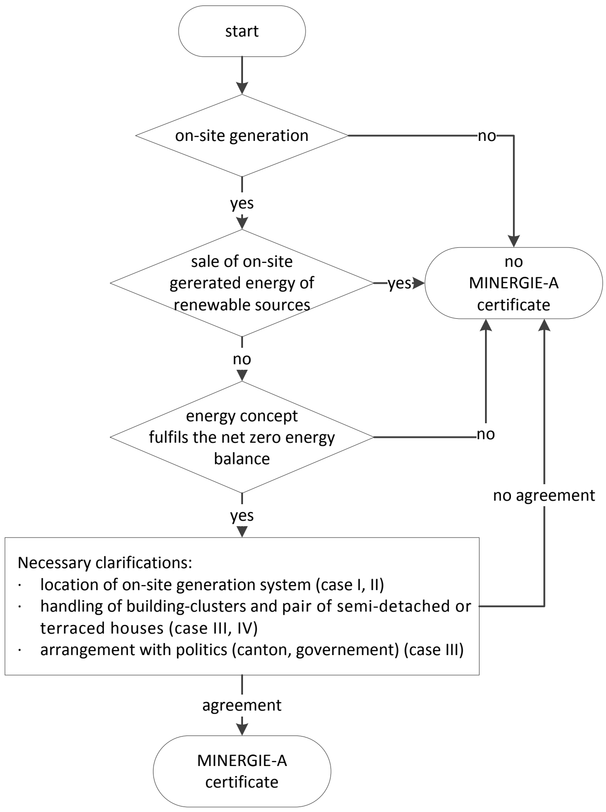

Figure 7: Steps with tracking the "use" of solar energy regarding the net zero energy balance to reach a MINERGIE-A certificate.

III Of the 176 MINERGIE-A buildings discussed above, 70 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. 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.

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 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 change. 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.

NEW PERSPECTIVES OF MINERGIE-A

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". A recast of the MINERGIE-A standard may therefore include a reduction of the embodied energy target value in the near future.

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 $kWh_{EPnren}/(m^2\,a)$. 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.

Grid interaction – 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 [7]. 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 fulfills a monthly balance for about 70-80 % and an hourly balance for about 30-40 % of the time [8]. MINERGIE is discussing a monthly balance and the use of asymmetric primary energy factors.

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 176 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 experience gained with realising 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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NOMENCLATURE

kWh_{end}	end use energy
kWh_{final}	final energy
kWh_{EPnren}	non-renewable primary energy [9]
kWh_{ECH}	primary energy, weighted with Swiss national weighting factors [5]
m^2	heated floor area (external dimensions)
Wp, kWp	peak PV power
KEV	"kostendeckende Einspeisevergütung"

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