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ONE YEAR MINERGIE-A – SWITZERLANDS BIG STEP TOWARDS NET ZEB

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Abstract

The worldwide discussion concerning the reduction of energy consumption and of greenhouse gas emission in the building sector has led to the design of low (Passive house), nearly or net zero energy buildings. The first available label standardizing a zero-balanced type of building is the Swiss standard Minergie-A. This standard was implemented by the Swiss association MINERGIE® in March 2011. The standard prescribes an annual net zero primary energy balance for heating, domestic hot water and ventilation. Electricity consumption for appliances and lighting is excluded. Additionally, Minergie-A is the first standard worldwide which includes a requirement in regard to embodied energy.

Due to these unique features, the Minergie-A standard leads to very important feedback for the implementation of a nearly or net zero energy building standard. Based on a analysis of 39 Minergie-A buildings this paper shows that a wide range of different energy concepts and embodied energy strategies are possible in the scope of the label. The basis of all Minergie-A buildings is a well-insulated building envelope, however. On-site energy generation is typically covered by the installation of a sufficient amount of photovoltaic collector modules. The requirement in regard to embodied energy is generally accepted by architects and designers.

The step from the Swiss standard Minergie-A to a net zero energy building standard (Net ZEB) which includes electricity consumption for appliances and lighting is not a very big one. Increasing the size of the photovoltaic system is sufficient in most cases. Some of the Minergie-A buildings evaluated are also Net ZEBs, anyway. In this paper, it is also shown that the net zero balance during the operational phase of Net ZEBs clearly outweighs the increased embodied energy for additional materials in a life cycle energy analysis.

Keywords: *net zero energy building, net zero energy balance, embodied energy, life cycle energy, primary energy*

1. Background

The Energy Performance of Buildings Directive [EU 2010] aims to achieve that by the end of 2010 all new buildings shall be "nearly zero energy buildings". In this context, two questions arise: Which metric should be nearly zero? And what does "nearly zero" mean? Although not a member of the European Union, the discussion about nearly and net zero energy buildings is also very lively in Switzerland. "Until 2020, all new buildings ideally cover their needs for heating and hot water with locally self-produced renewable energies and partly cover the electricity demand on an annual balance." This was announced by the Swiss conference of the cantonal energy directors in September 2011 [EnDK 2011]. Based on this target, a recast of the Swiss building energy code is under development.

The Swiss label MINERGIE® is a trailblazer in energy efficient buildings [Minergie]. The association was founded in 1994 and has since then driven the development of increasing thermal comfort and 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 "comfort ventilation" system. "Minergie-A" is the newest Minergie standard for residential buildings and was implemented in March 2011. The development of Minergie-A goes in line with the world wide discussion about nearly and net zero energy buildings. For the first time, a label requires a net zero energy balance. The three central requirements for a Minergie-A certificate are

- A Minergie-A building has a heating demand which is at least 10% lower than what is allowed according to the Swiss building regulations [SIA380/1:2009].
- Also, an annual net zero energy balance for space heating, domestic hot water, ventilation and auxiliary electricity is required. The primary energy balance is based on Swiss national weighting factors [EnDK 2009]. If the energy carrier for heating is wood and more than 50% of the space heating and domestic hot water is covered by solar thermal collectors, a credit of 15 $kWh_{ECH}/(m^2a)$ is given.
- The embodied non-renewable primary energy must not exceed 50 $kWh_{EPnren}/(m^2a)$. If the embodied energy exceeds this requirement, the difference can be compensated by electricity production with a photovoltaic system, however.

As in all Minergie standards, a mechanical ventilation system with heat exchanger, and energy efficient white goods are required. Additionally Minergie-A has a requirement for energy efficient fixed lighting. Operational energy for plug loads and lighting is not included in the requirements. Nonetheless, Minergie-A buildings are appropriate examples to evaluate the step towards Net ZEBs.

The paper starts with a analysis of the first 28 single family and 11 apartment Minergie-A buildings. In the second part, congruencies and discrepancies between Minergie-A and Net ZEBs will be looked at. The experience gained through one year of Minergie-A practice will be summarized at the end.

2. Experiences with Minergie-A

2.1 Heat demand

The heat demand should not exceed 90 % of the allowed heating demand according to the Swiss building regulations. In actual fact, this is standard practice in many parts of Switzerland, anyway. The mean value of the 39 buildings is 61 ± 12% of the Swiss limit or 23 ± 6 $kWh/(m^2a)$ (fig. 1). This value is very close to the requirement of Minergie-P (60%) and implies a very well insulated building envelope including triple glazing units. The strong variation shows that the architects use different energy concepts to fulfil the Minergie-A requirements.

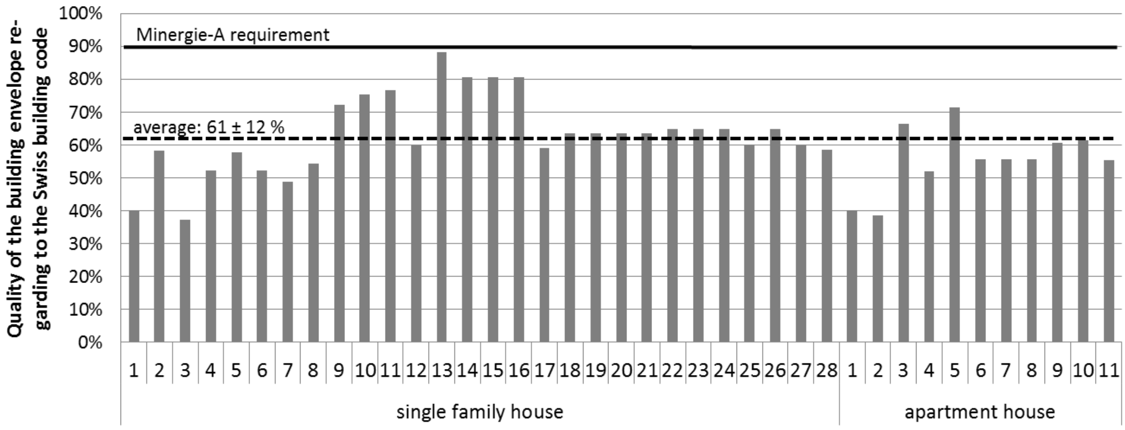

Figure 1: Quality of building envelope for Minergie-A buildings.

2.2 Net zero energy balance

The net zero energy balance includes space heating, domestic hot water, ventilation and auxiliary services. The primary energy balance is based on Swiss national weighting factors [EnDK 2009]. Only on-site production is taken into account. The quality of the envelope, the type and efficiency of the heating, hot water and ventilation systems determine the demand that has to be covered by renewable energy. The mean primary energy demand of all buildings is 29 ± 8 $kWh_{ECH}/(m^2a)$. Therefore, the actual level of the net zero energy balance strongly depends on the building (fig. 2).

Nearly all buildings use a photovoltaic system (PV) to produce the required amount of on-site energy. Table 1 shows average sizing values of the PV installation necessary to meet the net zero energy balance of the Minergie-A buildings. Only three of the considered buildings use the credit for the energy concept with wood and thermal solar collectors.

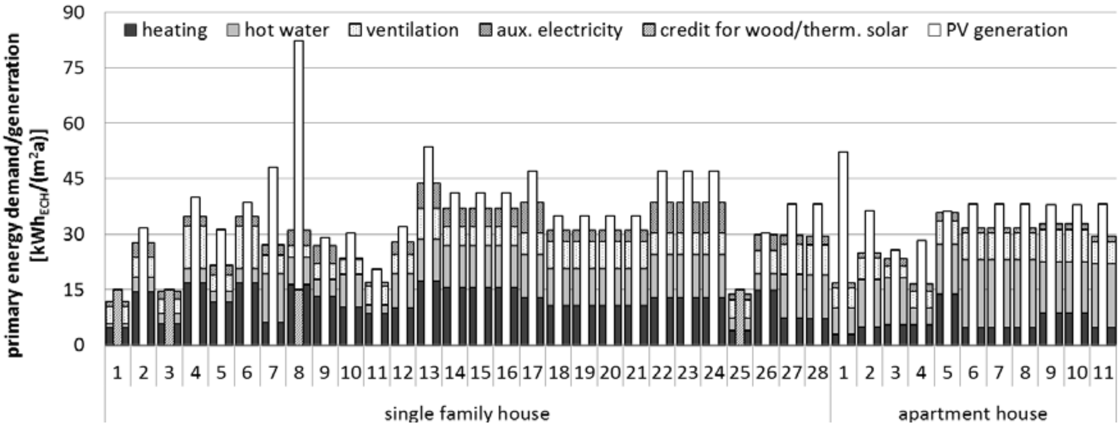

Figure 2: Net zero energy balance for primary energy demand/generation of the Minergie-A buildings.

Table 1: Average values for primary energy and photovoltaic systems to meet the Minergie-A net zero balance (39 buildings).

Average values	total	single family building	apartment house	unit
primary energy	29 ± 8	30 ± 9	28 ± 7	$kWh_{ECH}/(m^2a)$
Peak PV	11 ± 11	5.5 ± 3	22 ± 13	kWp
Peak PV / heated area	0.022 ± 0.01	0.022 ± 0.01	0.020 ± 0.01	kWp/m^2_{AE}
Area of PV / heated area	0.15 ± 0.05	0.16 ± 0.05	0.14 ± 0.03	m^2_{PV}/m^2_{AE}

2.3 Embodied Energy

The embodied energy of Minergie-A buildings includes the superstructure, building envelope, basement and the standard HVAC systems including distribution systems for heating, ventilation, cold/hot water and electricity. If thermal solar collectors and photovoltaic systems are part of the energy concept, they are included in the embodied energy calculation. The calculation is based on a cradle to grave analysis [MB2032 2010]. Two software programs are available, which are accepted for proof of compliance with the embodied energy requirement [Program].

Figure 3 shows the embodied energy of building construction and HVAC systems for the 39 Minergie-A buildings. Thermal solar collectors and photovoltaic systems are shown separately. The (non-renewable) embodied energy lies in the range of 34-53 $kWh_{EPnren}/(m^2a)$ with a mean value of 44 ± 6 $kWh_{EPnren}/(m^2a)$. In general, the building construction is the main contributor to the embodied energy and accounts for nearly 70% of the sum total.

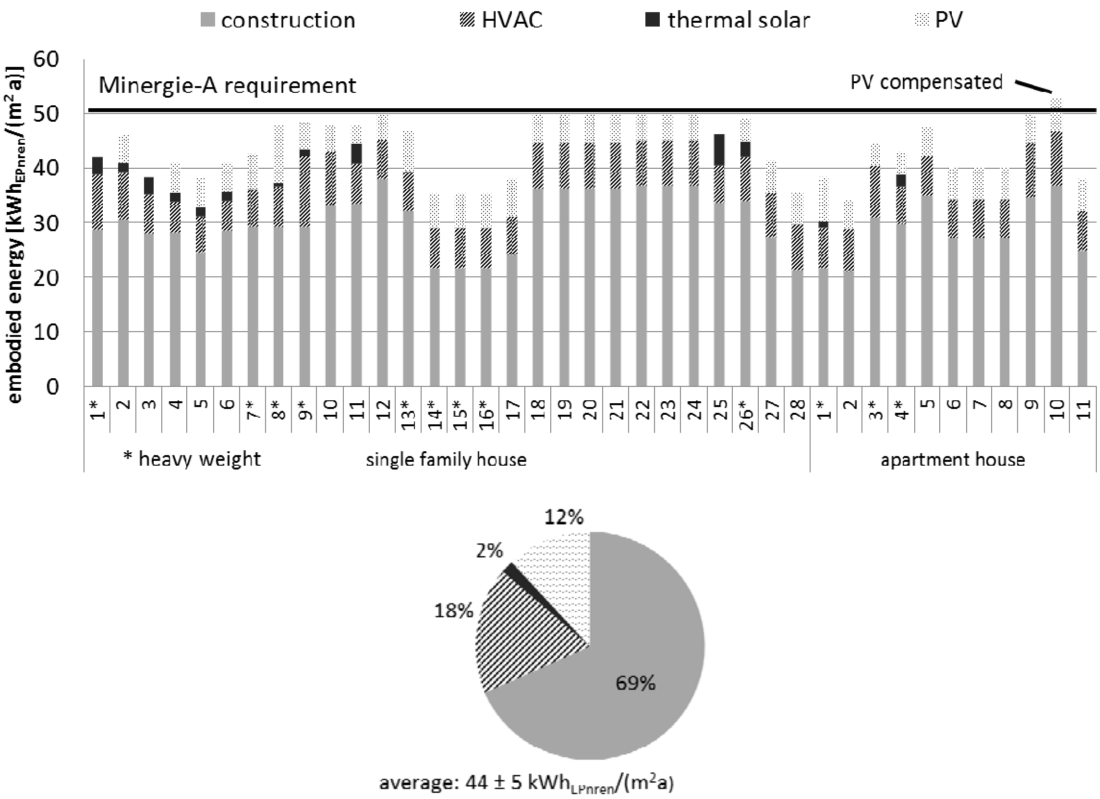

Figure 3: Composition and mean value of embodied energy for 39 Minergie-A buildings.

The correlation between the embodied energy for the building construction and the compactness of a building described as the ratio between heated floor area and building envelope area is given in figure 4. The construction style – heavy weight or light weight – is differentiated by in this figure. For apartment buildings, a discernible correlation between embodied energy for the building construction and the compactness of a building can be seen. However, there is practically no correlation between these parameters for single family buildings. The values for light weight and heavy weight buildings also do not show any strong bias, e.g. that light weight buildings have a significantly lower amount of embodied energy as compared to heavy weight buildings. This often stated "fact" could not be verified with the data available.

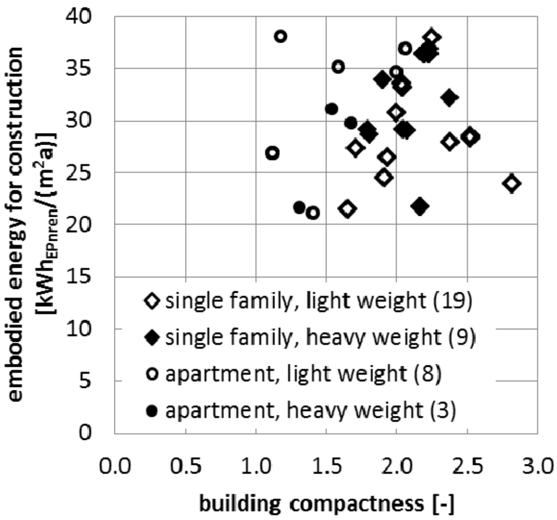

Figure 4: Correlation of embodied energy for building construction and building compactness depending of the construction style of the Minergie-A buildings.

3. From Minergie-A towards Net ZEB

3.1 Operational and embodied energy

The step from the Swiss Minergie-A standard to a net zero energy building is not a very big one. Simply increasing the size of the photovoltaic system is sufficient in most cases. Some of the Minergie-A buildings evaluated are also net zero energy buildings, anyway. In this paper, net zero energy buildings (Net ZEB) are defined as buildings that

- cover their total annual operational energy load,
- generate this on site by renewable sources,
- typically use photovoltaic systems and
- do not include the embodied energy in the balance, today.

The following analysis focuses on studying the trade-off between embodied and operational energy due to additional photovoltaic panel area necessary to take the step from Minergie-A to Net ZEB.

As a starting point, the Minergie-A buildings as described are used. The embodied energy is calculated based on non-renewable energy as before. The operational energy is recalculated based on non-renewable primary energy (table 2). It must be noted, here, that the factors used are from two different sources, each of which focus on slightly different goals / are influenced by different interests. Setting out from this starting point, two different building configurations are considered:

- the buildings are recalculated with enough PV to meet the Minergie-A balance
- the buildings are recalculated with enough PV to meet the Net ZEB balance

Table 2: Used primary energy factors [MB2031 2009], [EnDK 2009].

	SIA Merkblatt 2031 (non-renewable primary energy)	Swiss national factors (primary energy)
	f_{EPnren} [-]	f_{CH} [-]
CH-electricity, user mix	2.52	2.0
pellet	0.21	0.7
wood	0.05	0.7
district heating	0.79	0.6

Minergie-A does not include the operational energy for plug loads and lighting. Therefore, plug loads and lighting are considered with an across-the-board value of 42.8 $kWh_{EPnren}/(m^2a)$ for Net ZEBs. The size of the photovoltaic system is adapted to cover both the demand for plug loads and lighting. This, of course, results in a higher value of embodied energy for Net ZEBs.

Figure 5 shows the deviation of the operational energy and embodied energy in an overall assessment for different building types. The upper pie charts show the operational and embodied energy for the Minergie-A building with and without plug-loads and lighting. The embodied energy share is between half and two thirds of the total energy demand (figure 5, top left pie chart). Adding the operational energy for plug-loads and lighting shifts the share to one third embodied energy and one third for plug-loads and lighting and one third for thermal comfort systems (figure 5, top right pie chart). In the case of Net ZEBs, the additional area of photovoltaic panels necessary to cover the operational energy for plug-loads and lighting is considered in the calculation of embodied energy. Net ZEBs shows only a slight change in the share of total energy compared with Minergie-A including plug-loads and lighting (figure 5, bottom pie chart).

This comparison shows that the operational energy for plug-loads and lighting has a major impact not only on the shares of the total energy demand, but also on the absolute total energy demand. The total demand of Minergie-A buildings increases about 50% when plug-loads and lighting are considered and by about 70% for Net ZEBs.

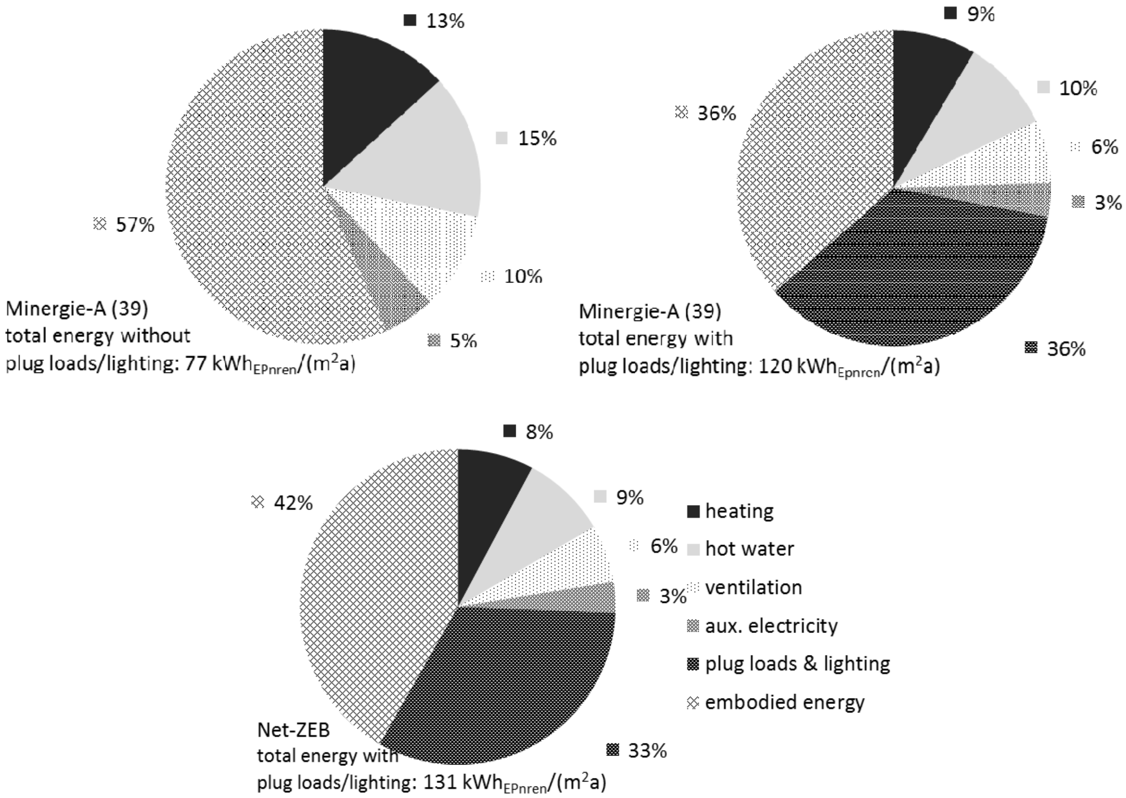

Figure 5: Operation energy and embodied energy share of total energy for the Minergie-A buildings (top) and the adapted net zero energy buildings (bottom).

3.1 Life Cycle Energy

Life cycle energy (LCE) includes the net-operational energy and the embodied energy. Due to the differences between the boundaries of net zero energy balance, the life cycle energy of a Minergie-A and a Net ZEB must also differ. Based on the Minergie-A buildings three different building configurations are considered:

- the buildings are recalculated with no PV (low energy building)
- the buildings are recalculated with enough PV to meet the Minergie-A balance
- the buildings are recalculated with enough PV to meet the Net ZEB balance.

Figure 6 shows the life cycle energy of a low energy building (without PV), a Minergie-A building and a Net ZEB. The net-operational energy includes the electricity for plug loads and lighting in all three cases. The increase of embodied energy from a low energy building to net zero energy building is about 25%. However, per definition, the net-operational energy is reduced to zero. The net zero energy balance of Minergie-A buildings and Net ZEBs clearly outweighs the increase in embodied energy for additional materials. This shows that the Net ZEB has the lowest life cycle energy. It is 60% lower than the life cycle energy of a low energy building. Therefore, a Net ZEB is preferable.

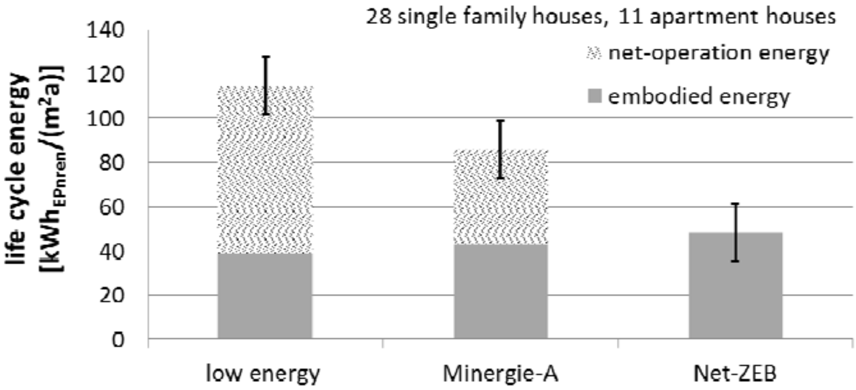

Figure 6: Life cycle energy of different building standards.

4. One year Minergie-A experience

4.1 General

During the first 16 months in which the Minergie-A standard has been available, 7 certified buildings have been built and 107 buildings are pre-certified. Currently, an additional 46 buildings which are in the planning phase are aimed to meet the standards criteria.

The requirement for embodied energy is not only being accepted, it is actually being honoured by the architects and designers as a new challenge in optimization. The embodied energy calculations show that the limit value is well chosen. It is not too onerous, i.e. it does not pose an insurmountable problem and thus a reason to skip Minergie-A. But it is sufficiently strict to force planners to make an effort to reach the limit. The additional work necessary for the calculation is not much criticized.

In general, the feedback of architects and designers is very good. They appreciate it that there is a label with a net zero energy balance including a limit for embodied energy. There has been an increase in enquiries about the availability of a Minergie-A standard for office buildings. This standard is under development, now. Some of the architects and designers would like to do more: e.g. a Net ZEB or include a requirement for mobility.

4.2 Use of solar energy

The use of solar energy is obligatory for Minergie-A buildings (fig. 7). Thermal solar collectors reduce the energy demand for heating and hot water. The electricity from photovoltaic systems substitutes the electricity to run the HAVC. A common energy concept is a very well insulated building envelope, a heat pump for heating and hot water and a photovoltaic system for on-site renewable energy generation. With a share of approximately 75 %, heat pumps are the main type heating system used.

In general, the generation system must be installed on-site. A special case in this regard is a small Minergie-A cluster of 68 single family terraced houses and 5 apartment buildings. As the apartment buildings could not fulfil the net zero energy balance on their own, they were allowed to use the surplus of the single family houses for their balance. With this, Minergie-A can be viewed to be taking the step from a building related net zero energy balance to a cluster related net zero energy balance. As the cluster only consists of four building types only one example of each building type is considered in the analysis in chapter 2.

To account the generated energy in the balance the generated energy may not be sold to a solar stock market or to the special Swiss fund for renewable energy. This Swiss fund is financed by a premium on electricity in Switzerland and in turn financially supports the installation of renewable energy sources.

These restrictions require the owner to choose between selling the electricity exported to the grid with the goal of refinancing the photovoltaic system or getting the Minergie-A certificate. These restrictions are based on the fact that the solar electricity should only count one time. Without these restrictions, more Minergie-A buildings would be certified. The upkeep of this restriction is currently being discussed. One of several issues in this regard is that ownership, tenancies and contracts change during the times. It’s not possible for Minergie to track such changes.

Figure 7: On-site generation.

4.3 Grid interaction

Minergie-A buildings are grid connected. Nearly every building has a photovoltaic system and interacts with the grid: it imports energy if the on-site generation is lower than the demand and it exports energy otherwise. The grid is used as a kind of storage or credit item. As the requirement of the net zero energy balance is on an annual basis, Minergie-A does not rate the time shift between demand and generation or the intensity of grid use. Figure 8 shows an example of the grid impact of Minergie-A and Net ZEB on a monthly base for a single family building. To fulfil the net zero energy balance of Minergie-A, the need of energy production through a photovoltaic system is much lower than to fulfil the net zero energy balance of Net ZEBs. Therefore, Minergie-A buildings have a much lower surplus in the summertime and the generation and demand correlate much better than for Net ZEBs.

To date, due to the low number of Minergie-A buildings and other buildings with photovoltaic systems, there is no discernible impact on the Swiss electricity grid.

As the political energy target is to cover the operational energy by renewable energy sources with on-site energy generation, grid control, electricity storage and electricity transportation for short time and seasonal aspects are major discussion topics. The reduction of fluctuations by on-site storage e.g. by small batteries in every building, intelligent control of HVAC and white goods to avoid peak loads and heat storage in the construction could help increase self-consumption and reduce grid interaction. All these subjects are current research topics and part of political debate.

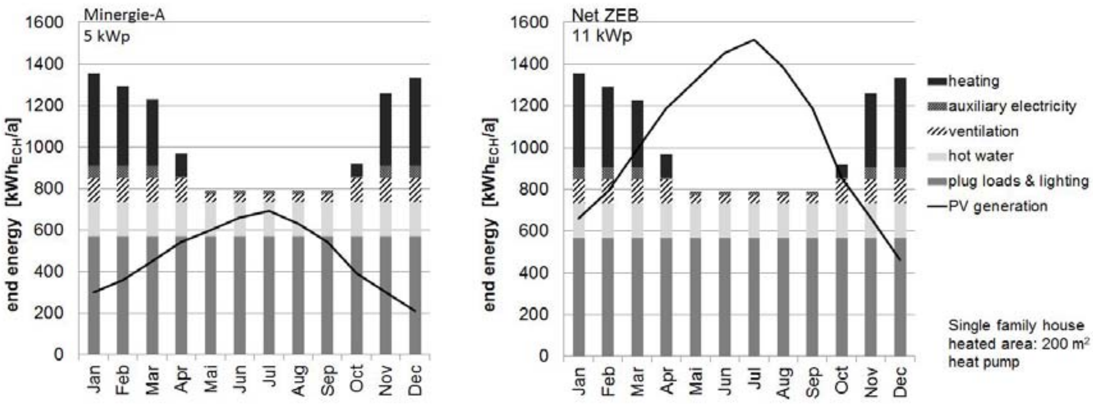

Figure 8: Grid interaction of Minergie-A and Net ZEB on a monthly base.

5. Summary

During the first 16 months after introduction of the Minergie-A standard, about 150 buildings applied for a certification. The concept of a net zero energy balance for HVAC is a challenge for architects and designers. Minergie-A allows different energy concepts to fulfill the requirements. The common Minergie-A building is very well insulated, features a heat pump and generates renewable energy on-site by photovoltaic panels. After one year of Minergie-A it can be clearly stated that a net zero energy balance is possible for single family and apartment houses. The additional requirement in regard to embodied energy is not too onerous but also not too relaxed. Architects and designer welcome that a limit for embodied energy is given.

The difference between Minergie-A and Net ZEB is that the net zero energy balance of Minergie-A excludes plug-loads and lighting. The comparison of life cycle energy shows that the life cycle energy of a Net ZEB is much lower than for Minergie-A. Concerning the life cycle energy, a Net ZEB is preferable.

Due to the larger collector areas necessary for Net ZEBs, however, the storage of the electricity generated on-site moves into focus even more. Grid interaction of such buildings must be looked into in more details, possibilities to increase on-site consumption should be identified.

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