TOWARDS THE DEVELOPMENT OF STRATEGIES FOR ENERGY-POSITIVE RESIDENTIAL BUILDINGS IN SWITZERLAND

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ABSTRACT

In this study the authors use building performance simulation to investigate the potential of state of the art technologies to support the identification of strategies for energy-positive building refurbishments, also plus-energy buildings. The methodology involves numeric optimization and parametric studies. The building case studied is a two-story one-family home with a double pitched roof. The building is representative for buildings erected before 1980 with a market share of more than 50%. Technologies considered include heat pumps in combination with PV-panels and solar thermal collectors. Two types of solar thermal collectors are differentiated: roof- and façade collectors. The results show that buildings oriented East/West have a higher potential to achieve a positive annual energy balance than buildings oriented North/South buildings. Further, the resulting twice peaking profile of the generated energy can be used to balance generation and demand profiles. It could be confirmed that PV-panels in combination with façade collectors have the potential to achieve a positive annual energy balance for North/South oriented buildings.

INTRODUCTION

The strategies for designing buildings change. Was the focus in the 90ies on minimizing the use of fossil fuel, is it nowadays on generating energy locally and using a smart grid for intelligent energy distribution.

The approaches have in common that they first aim at minimizing the energy demand and using renewable energy sources. The minimization of the energy demand is realized using passive design features and efficient building services.

However, whilst the approaches can easily be implemented designing new buildings, achieving a positive energy balance with existing residential buildings is due to the fixed building characteristics challenging. The aims of the study are (1) conducting a survey and documenting the existing experience with energy-positive residential buildings in Switzerland and (2) the development, evaluation and optimization of buildings and system concepts.

The residential building stock in Switzerland

94% of the buildings in Switzerland are used as residences. 60% of those are single family homes. A renewal rate of 1.5% per annum means that 45% of the residences that we will live in 2050 have been erected already. If the renewal rate drops to 0.75%, which is not an unlikely scenario given the current economic situation, 70% of the buildings we live in in 2050 already exist. The listed facts illustrate the importance of considering the existing building stock for achieving the European aims for CO_2 reductions. This paper aims at supporting the development of strategies for achieving a zero net energy balance for the existing residential building stock.

Balancing the energy demand

Definitions for energy positive building vary widely. The authors adopt the definition whereas the building specific generated energy equals or exceeds its demand. The demand is defined as energy used for providing domestic hot water, space heating, ventilation as well as small power and electrical equipment.

Different approaches to balance the generated energy demand are reported in the literature. Voss and Musall (2011) differentiate between balancing the generated energy versus the demand and balancing the delivered energy versus the exported energy over different temporal horizons (Voss and Musall, 2011). In this study the authors balance the generated energy versus the energy demand over one year.

METHODOLOGY

The study makes use of a number of research methods:

1. building and literature reviews;
2. numerical optimization of the system performance;
3. comparative performance study using dynamic thermal simulation.

Firstly, a literature and software review was carried out. The aim was to first identify the state-of-the-art in optimizing IBS's to achieve a positive energy balance. The literature study focused on review articles targeting tools for the generic optimization of virtual building models based on predefined cost functions.

Secondly IDA-ICE was coupled with GenOpt to numerically optimize important PV system parameter to maximize the energy generation.

Thirdly a parametric study was conducted to estimate the potential demand coverage for a combination of systems as heat pump; PV panels and solar thermal collectors.

ENERGY POSSITIVE BUILDINGS IN SWITZERLAND

The Swiss residential building stock consists of 1.6Mio buildings. 86% of the buildings are centrally heated, 9% is heated by stoves and 1.8% is heated by district heating (BFS, 2010). 81% of the buildings are heated with systems that are powered by fossil fuels (oil, gas, coal) 10% are heated with electricity and 9% are heated by heat pumps or solar thermal collectors (0.1%).

Table 1
Overview of the used technology top achieve energy-positive buildings Switzerland

TYPE	PV	ST	GSHP	CHP	COMMENT
New	x	x	/	/	HP A/W
Refurb.	x	x	/	/	Pellet fired boiler
New	x	x	/	/	Pellet-fired boiler
New	x	x	x	/	/
New	x	/	x	/	/
Refurb.	x	x	/	/	Wood fired boiler
New	x	/	x	/	/
New	x	/	x	/	/
New	x	/	/	/	HP A/W
SUM:	**9**	**5**	**4**	**0**	**/**

Abbreviations: New – New build; Refurb – Refurbishment; PV – Photovoltaic; ST – Solar thermal collectors; GSHP – Ground source heat pump; CHP – Combined heat and power; HP A/W – Air/water heat pump

The overview indicates that the current developments make extensive use of heat pumps; PV panels and solar thermal collectors. The question that arises is: "What is the potential of the used technologies for existing buildings? The question is being addressed using dynamic thermal simulation of a case study.

Solar collectors are placed on the roof and on the facades.

SYSTEM PERFORMANCE OPTIMIZATION AND EVALUATION

To answer the question we firstly identified a representative Swiss building layout and optimized PV Panel parameter for the location Zürich/ CH.

PV Panel parameter optimization

To ensure the highest possible solar energy harvest the design parameters for the panel installation were optimized. The parameters considered were area (length and width), orientation and panel inclination. Table 2 shows the optimal parameter settings for the PV-panels (Struck et al., 2011).

Table 2
Optimal parameter settings for PV Panel installation

	OPTIMAL PARAMETER SETTINGS
Area (m^2)	30
Orientation (deg.)	170
Inclination (deg.)	55°

For the parameter optimization IDA ICE v4.0 was coupled with GenOPTt. The coupling procedure requires the definition of the cost function – maximization of the harvest from the PV panels and the definition of the parameters to optimize. The optimized parameters were used for the subsequent parametric simulation study.

Case study description

The case study is based on a two-story Swiss residential building built in 1980, located in Zürich. The building is occupied by four people. It is equipped with a heat pump and under-floor heating.

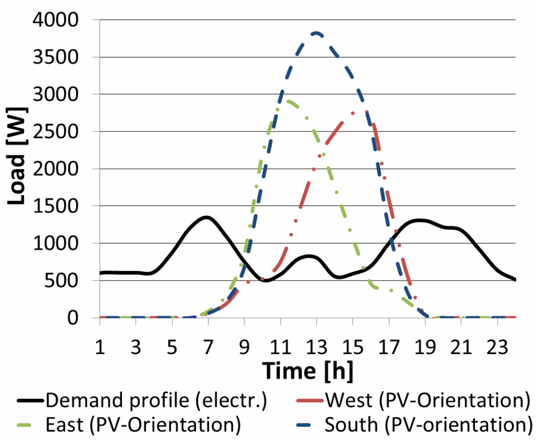

Figure 1: Final electrical demand and generation profiles for September 22nd.

The use profiles for heating, domestic hot water and electricity correspond to the Swiss average, see (Köhler, 2005, SIA, 2006). The locally generated energy originates from high performance photovoltaic panels. Figure 1 shows the generated used load profiles for the case study building for the building orientated south and East/West.

INTERGRATED SYSTEM PERFORMANCE

A number of cases were simulated differentiating two energy ventilation strategy - natural [/] and mechanical [Lü]; two energy performance standards - low[G] and - high [Z]; and two building orientations - South [Süd] as well as- East/West [OW], see table 2. The south facing cases are equipped with 30m^2 PV panels. The east/west oriented cases are equipped with 60m^2 PV panels on both sides of the double pitched roof.

Table 2
Ratio of used to generated electr. energy

		LOADS	GAINS	RATIO
POS.	CASES	[kWh]	[kWh]	[/]
1	Lü-G-Süd	7500	6500	0.87
2	Lü-G-OW	7500	9700	1.29
3	Lü-Z-Süd	7000	6500	0.93
4	Lü-Z-OW	7000	9700	1.39
5	G-Süd	8000	6500	0.81
6	G-OW	8000	9700	1.21
7	Z-Süd	7400	6500	0.88
8	Z-OW	7400	9700	1.31
Loads: domestic hot water + domestic electricity use + energy use for heating; **Gains:** from PV panels				

The results in table 2 show that the gain to load ratio easily exceeds 1 for the east/west [OW] oriented cases. The cases with only the south facing pitch equipped with PV panels do not achieve a positive annual energy balance.

However, the cumulative frequency distribution of the energy, see figure 2, shows that it is possible to increase the load to gain ratio from 0.93 to 1.25 if the heating and domestic hot water demand can be met by solar powered systems.

The following sections of this paper focus on achieving a positive energy balance for south facing residential buildings.

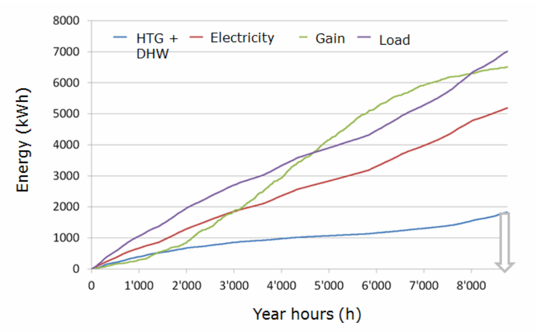

Figure 2 Cumulative frequency distribution for case 3; Lü-Z-Süd.

For this purpose three options are considered:

1. *replacing* a PV panels with 10m^2 and 20 m^2 solar collectors, respectively, and
2. *adding* 10m^2 and 20 m^2 *horizontal* solar collectors, respectively, to the PV panel installation.
3. *adding* 10m^2, 20 m^2 and 30 m^2 *vertical* solar collectors, respectively, to the PV panel installation.

The results for option 1 and 2 are indicated in table 3 and 4.

Table 3
Demand coverage for SCA 10m^2 (incl. 25^o)

	PV - SCA		PV + SCA
Cases	DC, thermal	DC, electr.	DC, electr,
Lü-Z-OW	26%	121%	135%
G-Süd	28%	57%	87%
Lü-Z-Süd	40%	69%	104%
Abbrev.: DC – Demand cover; SCA Solar collector area			

The results show that a positive energy balance cannot be achieved by replacing PV panels with solar collectors. However, by adding solar collectors a positive gain to load ratio can be achieved.

Table 4
Demand coverage for SCA 20m^2 (incl. 25^o)

	PV - SCA		PV + SCA
Cases	DC, thermal	DC, electr.	DC, electr.
Lü-Z-OW	35%	102%	139%
G-Süd	40%	31%	92%
Lü-Z-Süd	53%	37%	108%
Abbrev.: DC – Demand cover; SCA Solar collector area			

More simulations were conducted to identify the effect of vertically installed solar collectors (façade collectors) on the energy balance. The aim was hereby to identify the required area of the collector installation.

Figure 3 indicates the impact of façade collectors on the load to gain ratio for an East/West orientated building with 60m² PV panel area. The effect of the façade collectors is marginal. The average increase of the thermal demand coverage is 14%.

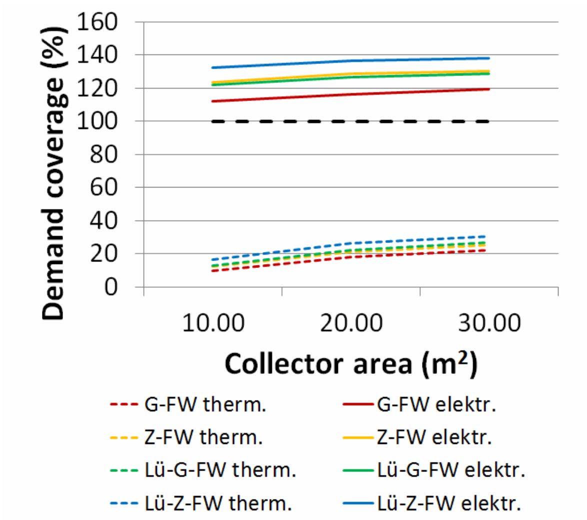

Figure 3 Impact of façade collectors on load to gain ratio for East/West orientated building.

Figure 4 indicates the impact of façade collectors on the load to gain ratio for an South orientated building with 30m² PV panel area. The effect of the façade collectors is significant. The thermal demand coverage can on average increased from 40 to 70%. That results in achieving a positive gain to load ratio between 10m² and 20m² façade collector area.

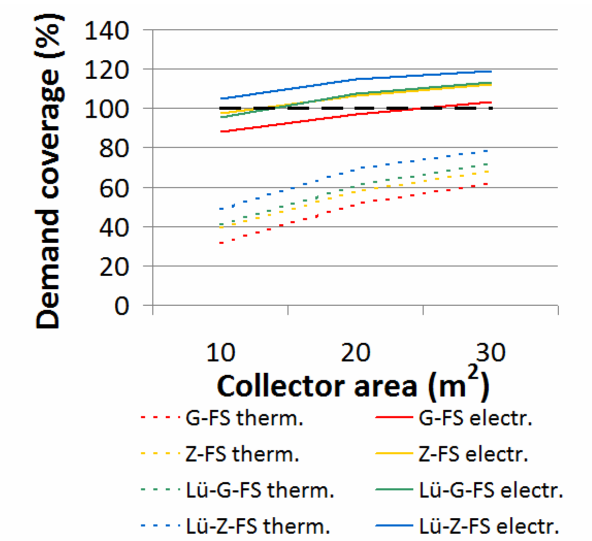

Figure 4 Impact of façade collectors on load to gain ratio for South orientated building

CONCLUSIONS

Current residential developments use heat pumps, solar thermal collectors and PV panels.

Adapting the technologies for residential buildings for achieving a positive energy balance is possible.

The mechanical ventilation system has with its 200kWh annual energy demand no significant impact on achieving a positive annual energy balance. Parameters which have a significant impact are domestic hot water and electricity use.

ACKNOWLEDGEMENT

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