# PLUSQUA

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## ABSTRACT

Buildings in an urban context can hardly achieve positive primary energy balances throughout a year due to the relative high density in the neighbourhood: ratio roof area to floor area (low active use of solar energy) and shading through other buildings (low passive use of solar energy). Depending on their location, plus energy buildings are not even desirable, since they unnecessarily stress the electricity grid [1]. For this reason, renovations on individual buildings shall be assessed in an overall concept at neighbourhood scale, expanding thus the considered system boundary. The aim of the project is to evaluate the additional benefit for the neighbourhood compared to a single house for specific typological, user-specific and technical interventions in terms of maximal thermal and electrical loads.
A typical Swiss urban neighbourhood [2] with a representative utilisation mix has been chosen in Cham in the canton of Zug to analyse the change of its thermal and electrical loads for different scenarios.

- **Networking:** Potential of connecting buildings electrically and thermally.
- **Utilisation mix:** Substitution of 20% and 50% office buildings into residential buildings.
- **Densification:** Increase of 20% and 50% space heating area in the neighbourhood.
- **Efficiency (Renovation):** Renovation of 20% and 50% of the actual building stock.
- **Decentralised production:** Impact of 0% up to 100% roof coverage of photovoltaics and impact of combined heat and power technology.
- **Storage:** Benefit of a daily and monthly thermal or electrical storage.

The scenarios were not set equally in relation with their economic investment, but according to their technical feasibility. The criteria used to define the additional benefits of each scenario were 1) the highest yearly average daily load, 2) the ratio between daily maximum load and daily mean load and 3) the difference between energy demand and energy supply.

The results show that the measures that reduce thermal loads the most are the renovation of 50% of the building stock. In order to reach the energy goals of the SIA 2040, additionally a substitution of the present fossil heating systems is required. If the present heating system based on fossil fuels would be substituted to 100% by heat pumps, the grid loads of the neighbourhood would be increased by at least 34%. Decentralised electricity production of photovoltaics does not additionally stress the transmission lines, although adjustments in the transformation stations would need to be made. Without demand side management, the electricity production from photovoltaic only reduces the grid demand peaks up to a certain point (≈40% of the roof area covered by PV ≈ 50’000 $m^2$).

The results show that the technical measures clearly have most impact on the peak load reduction, but due to their high costs, resulting in the present low retrofit rates, spatial planning measures present a good option to help mitigate thermal and electrical loads without major effort.

*Keywords: Energy strategies at neighbourhood scale, transformation building stock*

## INTRODUCTION

Buildings in an urban context can hardly achieve positive energy balances throughout a year due to the relative high density in the neighbourhood: ratio roof area to floor area (low active use of solar energy) and shading through other buildings (low passive use of solar energy). Depending on their location, plus energy buildings are not even desirable, since they unnecessarily stress the electricity grid. For this reason, renovations on individual buildings shall be assessed in an overall concept at neighbourhood scale, expanding thus the considered system boundary.

The aim of the project is to evaluate the additional benefit of the neighbourhood compared to a single house for specific typological, user-specific and technical interventions.

## METHOD

### Choice of the neighbourhood

The following requisites were set in order to define the typical neighbourhood of the suburban agglomeration of Switzerland:

- Frequent typology in urban areas
- High share of residential buildings with a retrofit potential
- Potential to change the utilisation mix in the neighbourhood or in the surrounding area.
- Potential for densification of the neighbourhood.

After analysing more than 10 neighbourhoods, “Cham Ost” near Zug has been chosen (Figure 1).

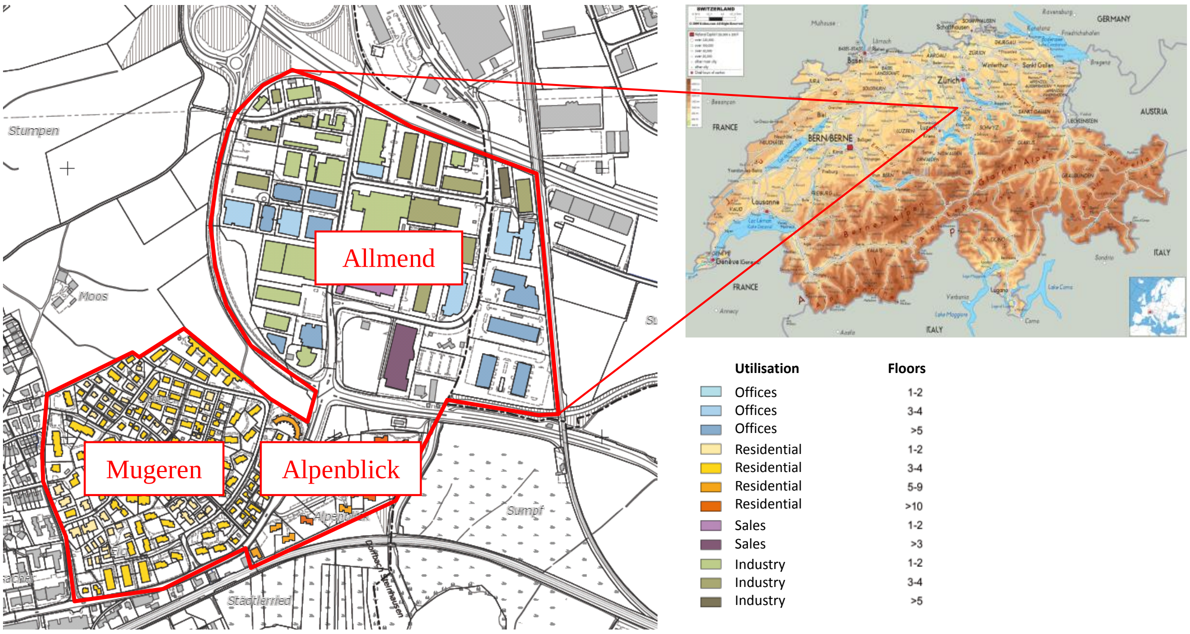
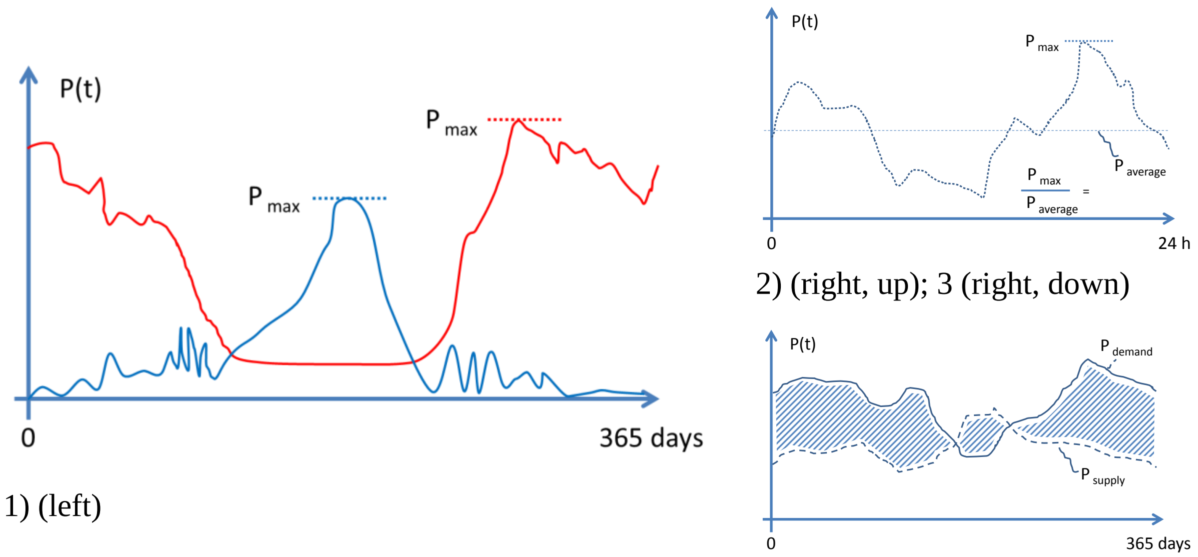


*Figure 1: Neighbourhood “Cham Ost” near the city of Zug divided into three subareas, Allmend (offices, sales and industry), Mugeren (residential buildings) and Alpenblick (high-rise buildings).*

### Criteria for the evaluation

The criteria used to define the additional benefits of the intervention measures were 1) the highest yearly average daily load, 2) the ratio between daily maximum load and daily mean load and 3) the difference between energy demand and energy supply (Figure 2).



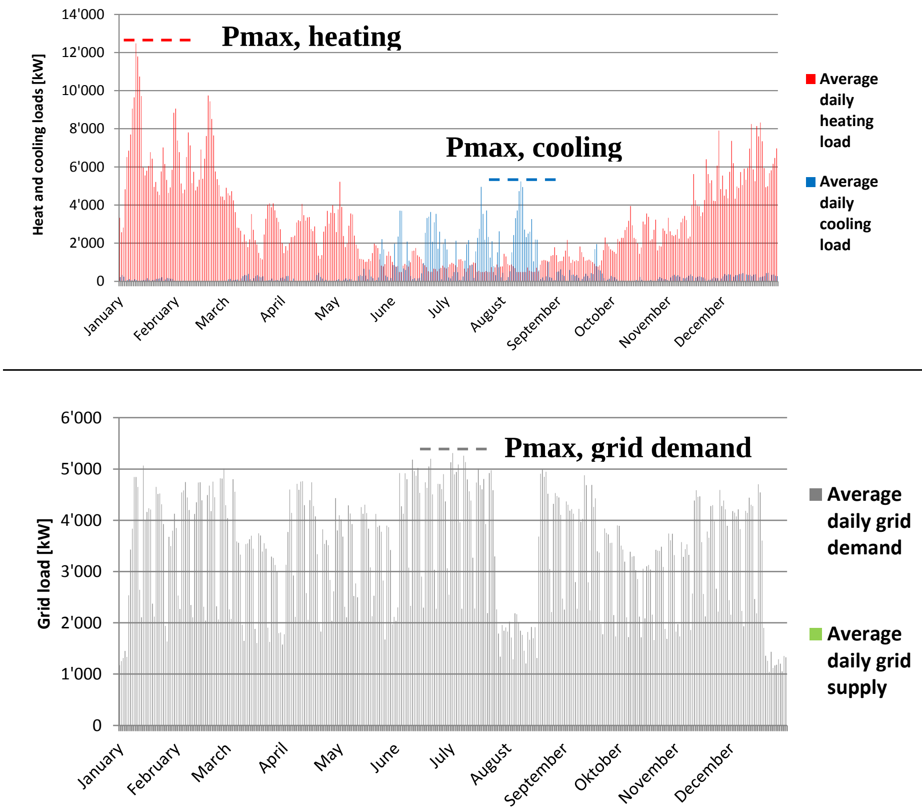
1) (left)

2) (right, up); 3 (right, down)

*Figure 2: Criteria for the evaluation of the scenarios in the neighbourhood.*

### Thermal and electrical loads of the neighbourhood "Cham Ost"

The thermal loads of the neighbourhood were determined by means of thermal simulations in IDA-ICE. 16 representative buildings were chosen, modelled and simulated to reproduce the entire neighbourhood. The electrical loads of the neighbourhood were assessed by using measured data on buildings of the same type in the same region. The profiles were then proportionally summed up accordingly to their surface share in the neighbourhood.



Pmax, heating

**12.5 MW**

Pmax, cooling

**5.2 MW**

Heating / Cooling demand

**25.8 / 3.5 GWh**

Pmax, grid demand

**5.3 MW**

Pmax, grid supply

**0 MW**

Grid demand / supply

**27.7 / 0 GWh**

*Figure 3: Thermal loads of the neighbourhood "Cham Ost" (upper graph) and electrical loads (lower graph) of the neighbourhood "Cham Ost".*

### Scenarios

Different scenarios were analysed in order to assess their potential according to the defined criteria. The scenarios were not set equally in relation with their economic investment, but according to their technical feasibility in the neighbourhood.

- **Networking:** Potential of connecting buildings electrically and thermally.
- **Utilisation mix:** Substitution of 20% and 50% office buildings into residential buildings.
- **Densification:** Increase of 20% and 50% space heating area in the neighbourhood.
- **Efficiency (Renovation):** Renovation of 20% and 50% of the actual building stock.
- **Decentralised production:** Impact of 0% up to 100% roof coverage of photovoltaics and combined heat and power technology.
- **Storage:** Benefit of a daily and monthly thermal or electrical storage.

## RESULTS

The most important results are briefly presented for two scenarios, efficiency and decentralised production of photovoltaic panels.

### Efficiency (Renovation)

The results show that in order to reach the goals of the SIA 2040 (target value for operation), 50% of the building stock shall be renovated to actual standard and 100% of the fossil fuel heating system shall be replaced by heat pumps with a yearly COP of at least 3.5 (Figure 5).

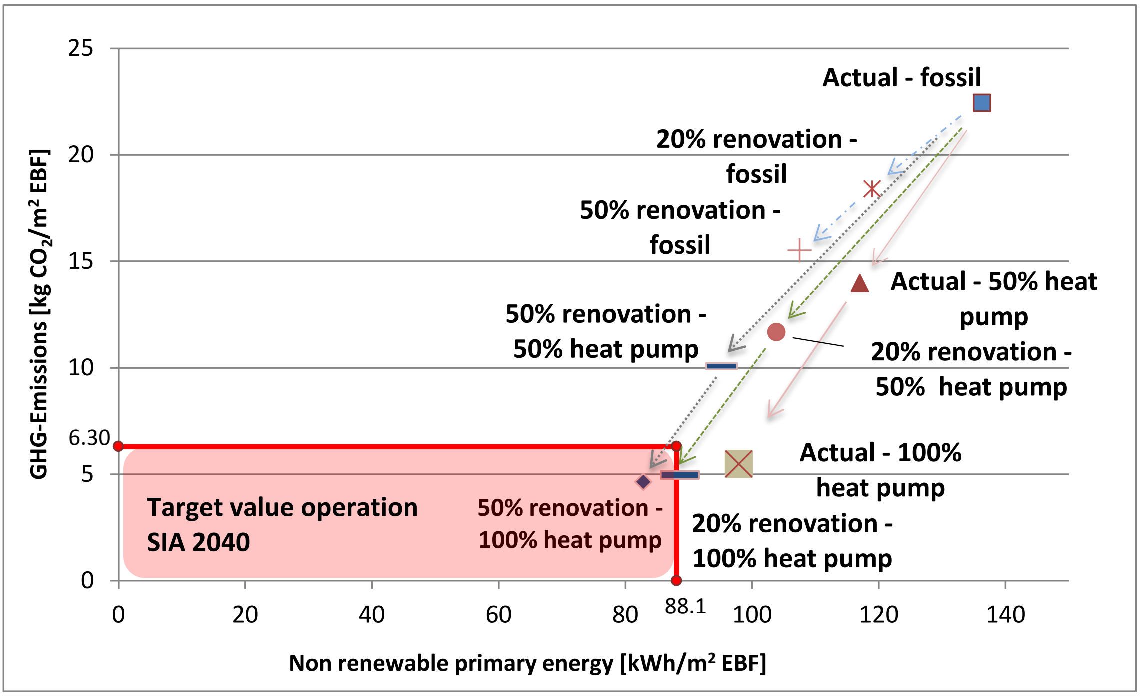
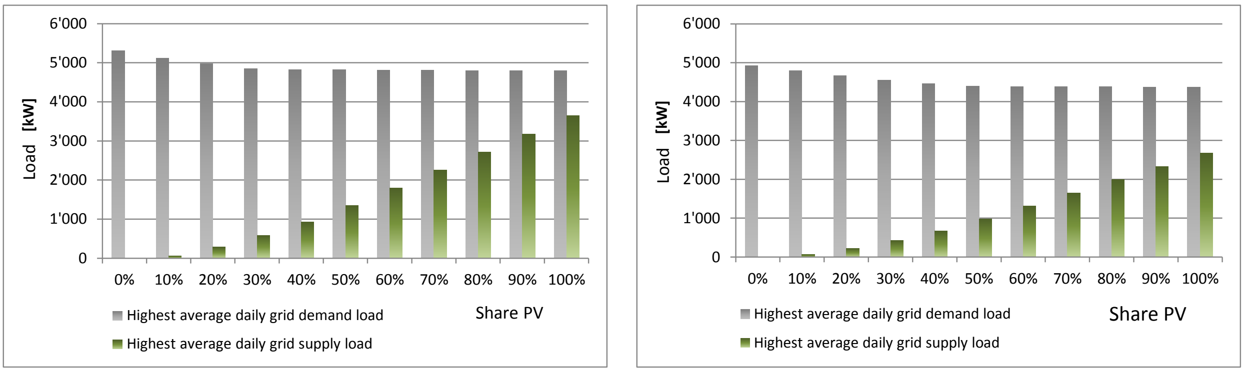


*Figure 5: Renovation strategies on buildings for the neighbourhood and environmental impact according to SIA 2040 (target value in operation).*

### Photovoltaic production

The results show that even if 100% of the roof surface of the whole neighbourhood is covered by photovoltaic panels, the transmission lines not additionally stressed, i.e. the maximum grid supply load does not exceed the maximum grid demand load. Without demand side management, decentralised production of electricity can only reduce up to certain percentage roof coverage (40% of the roof area = about 50’000 m$^2$) the grid demand peak.

**Neighbourhood „Cham Ost“** **Allmend (offices, industry, sales)**



**Mugeren (residential buildings)** **Alpenblick (high-rise buildings)**

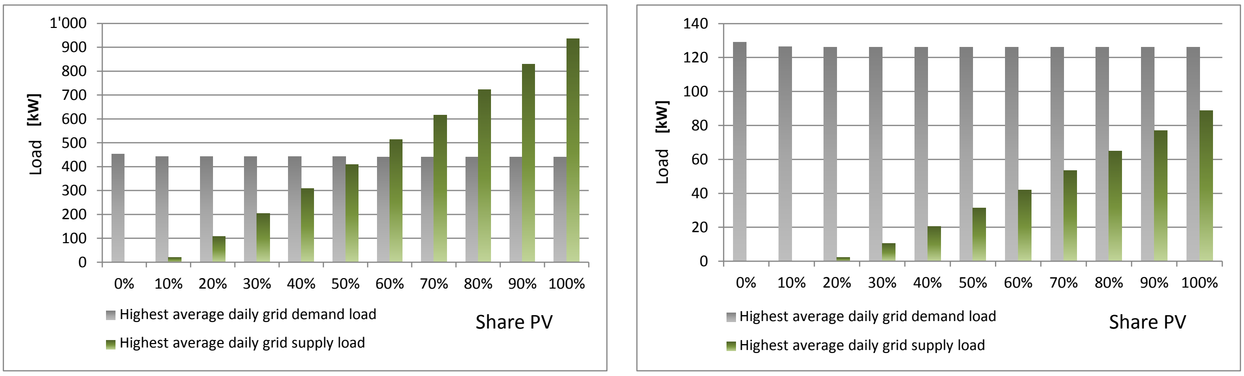


*Figure 4: Maximum grid demand (grey) and grid supply peak from PV (green) of the whole neighbourhood and the three subareas when 0% up to 100% of the roof surface is covered by photovoltaics.*

## Summary of the scenarios

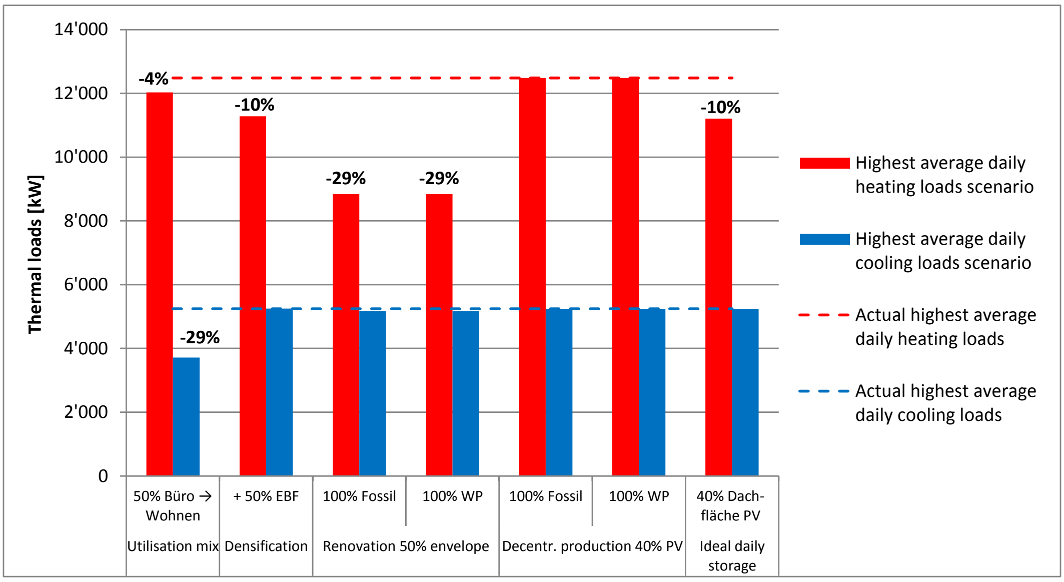


*Figure 7: Highest daily average during the year of the thermal loads of the different scenarios (histograms) compared to the actual state (dashed line) by the same surface.*

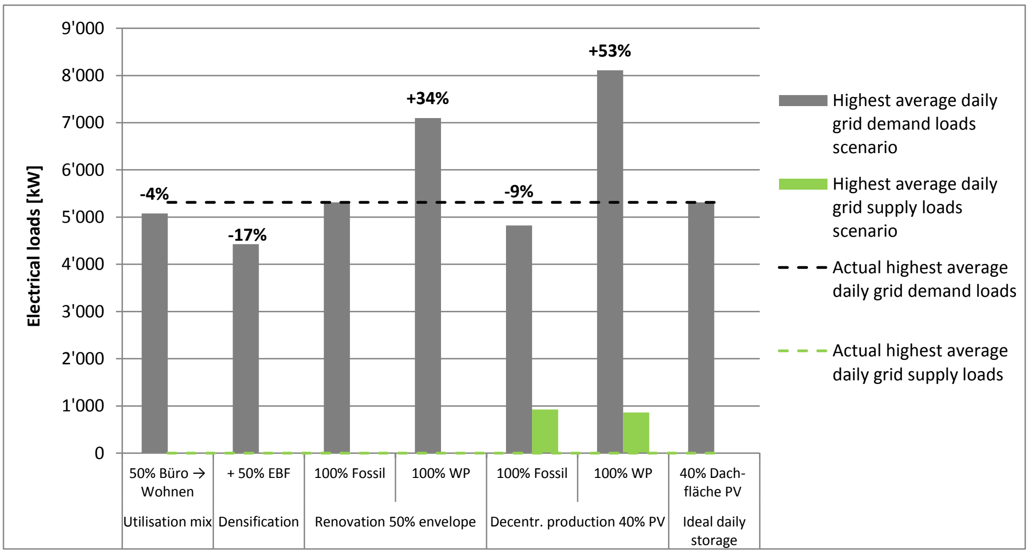


*Figure 6: Highest daily average during the year of the electrical loads of the different scenarios (histograms) compared to the actual state (dashed line) by the same surface.*

The scenario that has most impact on the thermal loads, without increasing the cooling loads, is the renovation of 50% of the building stock in the area. The conversion of offices into residential buildings reduces both heat and cooling loads, since residential buildings carry a higher specific storage mass than offices. If all internal waste heat would be reused for heat purposes on site, final energy demand could be reduced by 3.5 GWh and maximum heat loads can be reduced by around 10%. Densification of the neighbourhood with residential and office buildings reduces the specific electric loads of the neighbourhood, since the present specific electricity demand due to industry is high. Decentralised production of photovoltaic reduced down to 9% the grid demand peak, while increasing the grid supply. The substitution of fossil fuels with heat pumps increases grid demand load by 34% resp. 53%, according to the renovation state.

## DISCUSSION

The peak loads engendered by the use of heat pumps shall be considered as a major issue for the future electricity network capacity and shall be diminished as much as possible, for example by means of demand side management or with the use of high efficient heat pumps. The neighbourhood “Cham Ost” has nowadays an insignificant share of electricity production by photovoltaics. Electricity production by photovoltaic does not present any capacity problems for transmission lines. The only issue of electricity produced by photovoltaic is how to feed back the excess electricity back into the grid’s next level. This can be handled by integrating storage devices or reactive power compensation elements in the local transformation stations. The overall results show that the technical measures on individual buildings clearly have most impact on peak load reduction, but due to their high costs, resulting in the present low retrofit rates, spatial planning measures still present a good option to help mitigate thermal and electrical loads without major effort.

## REFERENCES

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