# SOLAR THERMAL POTENTIAL IN THE BUILDING STOCK – ACHIEVABLE LEVELS OF SOLAR THERMAL ENERGY SUPPLY

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**Abstract**

The solar thermal potential for domestic hot water and heating purposes has been assessed for over 1'000 existing buildings in Switzerland. The guiding principle of this study is i) to assess this solar thermal potential on a new solid basis starting from the buildings in different urban textures the way they exist today and ii) to analyze both the current potential with conventional systems and how the potential could develop along two axis: what is the potential with the same existing building stock being improved in terms of energy efficiency and / or using more advanced solar thermal (storage) systems? Two different building stocks have been examined, i.e. the densely urbanised area of the city of Zurich and the more rural area of the canton of Fribourg. The resulting achievable levels of the solar share in thermal energy supply in the residential sector vary from 19 to 43% for the city of Zurich and from 34 to 67% for the canton of Fribourg. Thanks to the innovative approach applied, detailed and corroborated results can be generated in an efficient manner and provide strategic input for decision makers in industry, research and policy on the important role of solar thermal systems in the energy supply in the residential building stock.

## 1. Purpose of the work

The potential of solar energy is, at least on the theoretical level, outstandingly high. Modelling of mostly new buildings indicates that their energy household can be 100% solar-based (solar thermal and solar photovoltaic energy, on a yearly basis). However, most building traditions and most existing buildings today have not really taken into account the solar thermal potential for domestic hot water and heating purposes. What is the potential of solar thermal energy in the building stock the way it exists today and with today's conventional solar thermal systems? What would be the potential for the same building stock provided it gets energetically renovated towards modern energy efficiency standards? And / or what would be the potential with most advanced solar thermal systems (especially advanced storage systems)? The purpose of the work performed is at least two-fold:

- Designing and simulating solar thermal systems in different energy supply systems of various buildings with variable energy need patterns can be rather complicated. Yet, the goal is to develop an approach that allows to condensate the vast variety and relative complexity of such solar thermal systems in a way that substantial, manageable and yet sufficiently accurate indices can be provided and used. Finally, these succinct indices bring together a set of highly relevant energy and building data like energy supply and yield, suitable roof area, energy reference area, etc.

- Based on a detailed analysis on the current and future potential in the existing building stock, the results should provide solid input for strategic orientations and priorities for the solar and building sector as well as for research, programming and policy.

Developing a new and efficient approach and providing corroborated and concise results constituted the main reasons for the Swiss Federal of Office to support this analysis.

## 2. Approach

The approach combines different databases, instruments and methods from solar simulation tools to geographic information systems. Two of the main ingredients are extensive statistical building data as well as specifically collected data on the solar morphology of buildings and regions (solar energy yields, solar technology integration opportunities, etc.). This approach has been developed and validated throughout the last 15 years on the regional and international level mainly in the context of photovoltaic potential assessments [1-3].

The approach is for the first time thoroughly refined and completed with extensive solar thermal data. One of the core elements is the simulation of different energy reference systems reflecting a set of different energy needs / efficiencies and solar thermal systems with the support of Polysun / SPF Rapperswil [4]. These references are transferred to each of the 1'210 buildings assessed (1'000 buildings in the canton of Fribourg and 210 buildings in the city of Zurich) showing both their current / conventional solar thermal potential [5-7] and the future potential with progressive energy standards and / or advanced solar systems. Table 1 shows the list of four reference systems used in the residential building stock.

Table 1. Reference systems according to thermal energy needs (four options with domestic hot water demand shown below) and storage capacity.

| **Reference systems** | **Thermal energy needs per $m^2$ energy reference area** | **Storage capacity per $m^2$ collector surface area** |
|---|---|---|
| 104-100l | 104 kWh:<br>80 kWh for heating purposes and 24 kWh for domestic hot water | 100 liter |
| 54-100l | 54 kWh:<br>30 kWh for heating purposes and 24 kWh for domestic hot water | 100 liter |
| 104-opt | 104 kWh:<br>80 kWh for heating purposes and 24 kWh for domestic hot water | Storage optimised |
| 54-opt | 54 kWh:<br>30 kWh for heating purposes and 24 kWh for domestic hot water | Storage optimised |

An essential part of the approach is to actually base the analysis on the current buildings and urban patterns as this "heritage" significantly impacts the potential of solar thermal energy supply that could be tapped in the next decades to come.

As mentioned above, one of the goals of this work consists of breaking the great diversity and complexity of solar thermal systems down to handy indices being derived by the following two tandems / steps approach:

- Suitable roof surface area and roof surface area potential index: The first step is to assess the suitable roof surface areas taking into account irradiation, orientation, obstacles, shading caused by trees or other buildings, etc. The suitable roof surface area is then indexed to the building ground floor area resulting in the roof surface area potential index.
- Weighted collector surface area and solar thermal potential index: The second step is to weight the suitable roof surface area in terms of best oriented (collector) surface area. Sub-optimal orientation of the roof surface area implying lower solar energy yields is therefore evaluated with a correction factor in order to calculate the weighted collector surface area. The weighted collector surface area is then indexed to the energy reference area resulting in the solar thermal potential index.

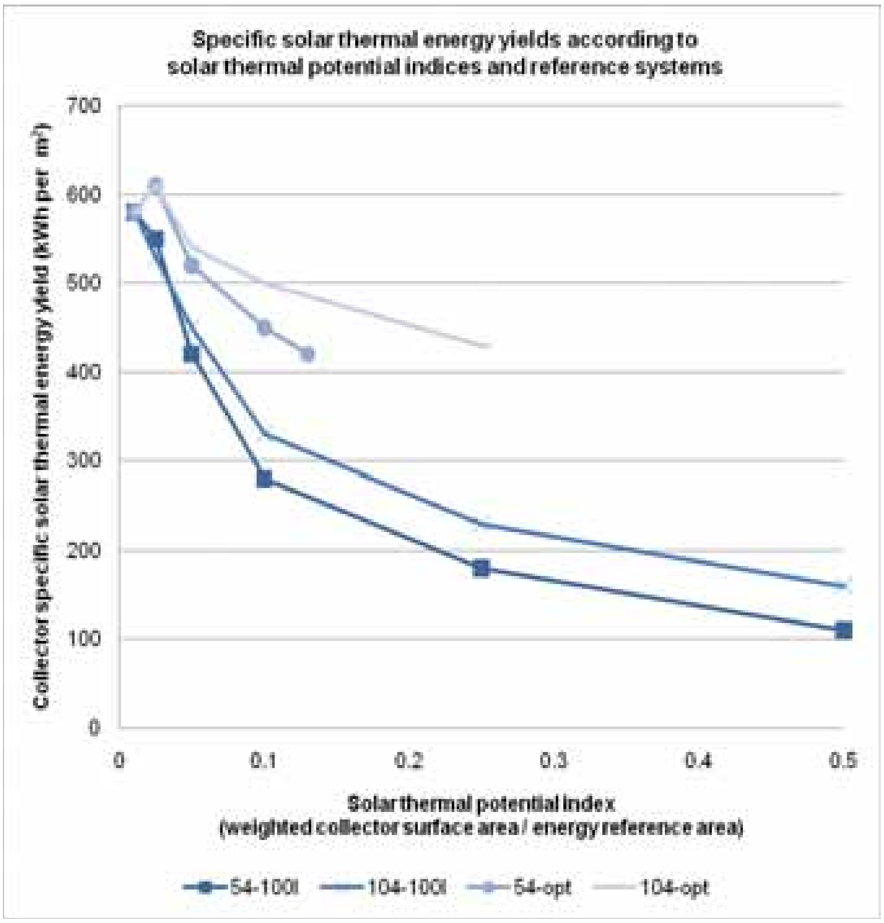


Fig. 1. Specific solar thermal energy yields according to solar thermal potential indices and reference systems.

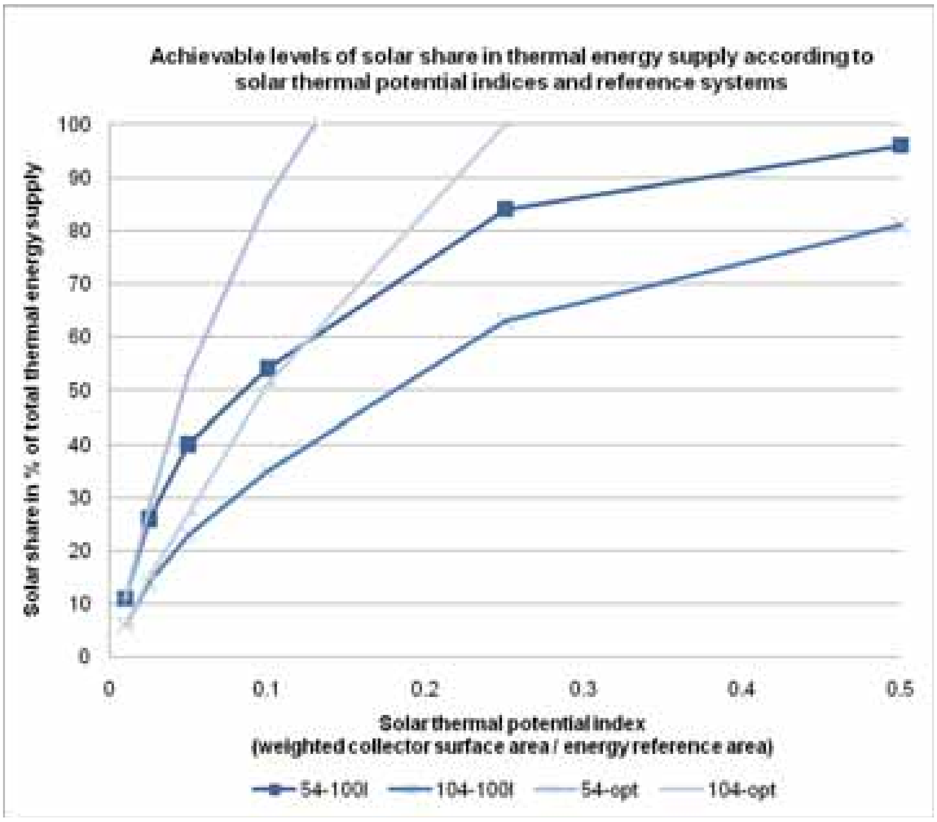


Fig. 2. Achievable levels of solar share in thermal energy supply according to solar thermal potential indices and reference systems.

## 3. Results

Some key results can be given for the two regional building stocks analysed along the following assessment steps and indices mentioned above:

- Suitable / unsuitable roof area,
- Solar thermal potential indices
- Solar shares in thermal energy supply

### 3.1 Suitable roof surface area indices

The suitable roof surface area indices are interestingly pretty similar for both building stocks in the city of Zurich and the canton of Fribourg, namely 32%. That is 32 $m^2$ of suitable roof area can be found per 100 $m^2$ of residential building ground floor area. This is true for the figures concerning the whole residential building stock but there are more important differences between building categories and / or regions.

Looking at the factors that reduce the roof surface area potential, it can be stated that the ranking of the reduction factors is similar with however some notable differences in terms of their relative importance. The reduction factors and their respective "loss share" for the canton of Fribourg respectively the city of Zurich are as follows:

- Orientation of the roof surface area: 62% for Fribourg resp. 54% for Zurich
- Roof shape and obstacles: 34% for Fribourg resp. 39% for Zurich
- Shading due to trees: 3% for Fribourg resp. 6% for Zurich
- Shading due to buildings: 1% for both Fribourg and Zurich

### 3.2 Solar thermal potential indices

Considerable differences occur with respect to the solar thermal potential indices that are 11,7% for the canton of Fribourg and 4,8% for the city of Zurich. This means that per 100 $m^2$ of energy reference area a potential of 11,7 $m^2$ of weighted collector surface area can be assessed in the canton of Fribourg and 4,8 $m^2$ in the city of Zurich.

The main reasons for the higher indices for the residential building stock of the canton of Fribourg are firstly the fact that there is much less energy reference area "under the roof" (mainly less storeys in the buildings of the canton of Fribourg with its relatively high share of single-family houses) and secondly the higher share of optimally south-oriented roof surface areas.

Table 2. Indices for the residential building stock in the canton of Fribourg and city of Zurich

| **Indices** | **Residential building stock of the canton of Fribourg** | **Residential building stock of the city of Zurich** |
|---|---|---|
| Roof surface area potential index | 32,1% | 31,6% |
| Solar thermal potential index | 11,7% | 4,8% |

Table 3. Solar thermal potential indices for different residential buildings in the canton of Fribourg and city of Zurich

| **Solar thermal potential indices** | **Residential building stock of the canton of Fribourg** | **Residential building stock of the city of Zurich** |
|---|---|---|
| Single-family houses | 17,4% | 7,8% |
| Multi-family houses | 9,4% | 5,3% |
| Residential buildings with mixed use (mainly residential purpose) | 11,8% | 4,2% |
| Residential buildings with mixed use (mainly other than residential purpose) | 7,2% | 3,1% |
| *Total residential building stock* | *11,7%* | *4,8%* |

### 3.3 Solar shares in thermal energy supply

The achievable levels of the solar share in thermal energy supply in the residential sector vary according to the reference system and available surface areas from 19 to 43% for the city of Zurich and from 34 to 67% for the canton of Fribourg.

Table 4. Achievable levels of the solar share in thermal energy supply in the residential building stock in the canton of Fribourg and city of Zurich according to the reference system

| | **104-100l** | **54-100l** | **104-opt** | **54-opt** |
|---|---|---|---|---|
| Canton of Fribourg | 34% | 55% | 50% | 67% |
| City of Zurich | 19% | 34% | 26% | 43% |

Table 5. Achievable levels of the solar share in thermal energy supply in the residential building stock in the canton of Fribourg according to the reference system

| **Achievable levels of solar share in thermal energy supply in the canton of Fribourg** | **104-100l** | **54-100l** | **104-opt** | **54-opt** |
|---|---|---|---|---|
| Single-family houses | 42% | 64% | 62% | 75% |
| Multi-family houses | 29% | 49% | 42% | 60% |
| Residential buildings with mixed use (mainly residential purpose) | 36% | 59% | 55% | 72% |
| Residential buildings with mixed use (mainly other than residential purpose) | 26% | 45% | 37% | 57% |
| *Total residential building stock* | *34%* | *55%* | *50%* | *67%* |

Table 6. Achievable levels of the solar share in thermal energy supply in the residential building stock in the city of Zurich according to the reference system

| **Achievable levels of solar share in thermal energy supply in the city of Zurich** | **104-100l** | **54-100l** | **104-opt** | **54-opt** |
|---|---|---|---|---|
| Single-family houses | 24% | 39% | 37% | 52% |
| Multi-family houses | 21% | 37% | 29% | 48% |
| Residential buildings with mixed use (mainly residential purpose) | 17% | 31% | 23% | 39% |
| Residential buildings with mixed use (mainly other than residential purpose) | 13% | 24% | 18% | 30% |
| *Total residential building stock* | *19%* | *34%* | *26%* | *43%* |

Figures 3 and 4 show what parts of the buildings reach what levels of solar share in thermal energy supply along the four reference systems by means of six categories (with respective solar shares of 0-9%, 10-29%, 30-49%, 50-69%, 70-99% and 100%+).

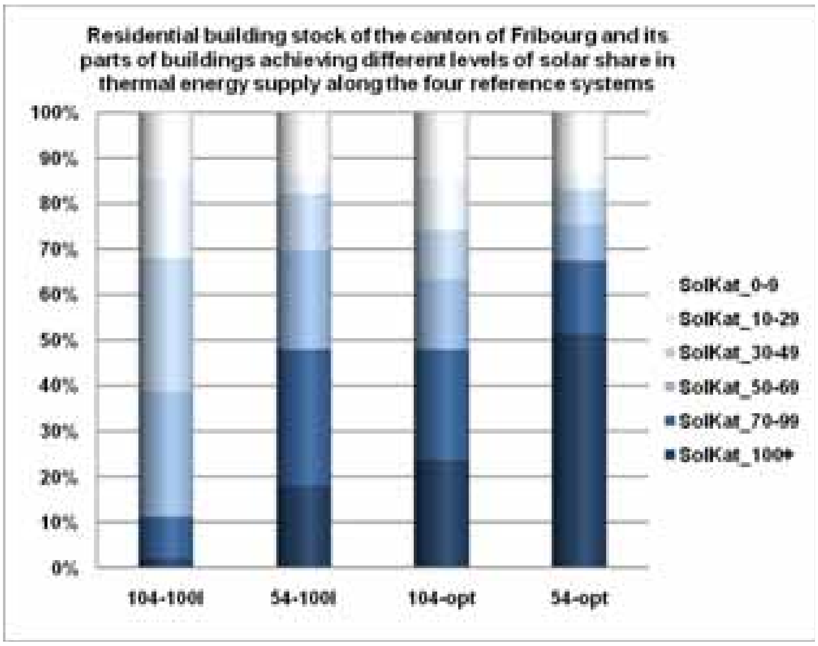


Fig. 3. Residential building stock of the canton of Fribourg and its parts of buildings achieving different levels of solar share in thermal energy supply along the four reference systems.

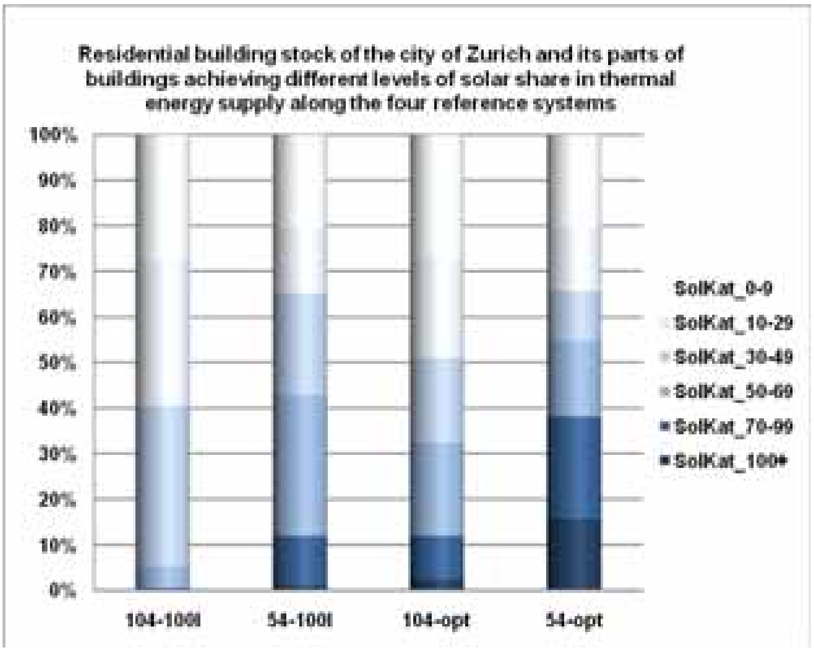


Fig. 4. Residential building stock of the city of Zurich and its parts of buildings achieving different levels of solar share in thermal energy supply along the four reference systems.

Looking at the levels of the solar share in thermal energy supply of individual objects, it can be stated that a significant number of buildings can achieve good and high solar shares. For instance, fixing a minimum solar share of 30% within the reference system of 54-100l (i.e. building with high energy efficiency but conventional solar thermal system), 83% of the buildings in the canton of Fribourg and 66% of the buildings in the city of Zurich can potentially fulfil this criterion.

## 4. Conclusions

The study of the solar thermal potential in the building stock and achievable levels of solar thermal energy supply [8] results not only in robust potential with a wealth of detailed and corroborated data for different building types (type of use, construction, listed buildings, etc.), various urban patterns and differentiated for reference energy standards and solar thermal systems but also fundamental input for strategic orientations and priorities for the solar and building sector as well as for research, programming and policy.


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## References


[1] Nowak S., Gutschner M., Abschätzung des PV-Flächenpotential im schweizerischen Gebäudepark, 1996

[2] IEA PVPS, Potential for Building-Integrated Photovoltaics, 2002, Report IEA-PVPS T7-4

[3] Nowak S., Gutschner M., Le Potentiel Solaire dans le Canton de Genève, 2004

[4] Ruesch F., Brunold S., Frank E., Simulationsstudie zur Potenzialabschätzung für den Einsatz von Solarthermie in der Schweiz, 2009

[5] Nowak S., Gutschner M., Gnos S., Potenzialabschätzung für Sonnenkollektoren in der Stadt Zürich, 2007

[6] Energie Schweiz/BFE, Dimensionierung von Sonnenkollektoranlagen, 2006

[7] Lutz, H.-P., Landesgewerbeamt Baden-Württemberg, Solaranlagen zur Warmwasserbereitung und Heizungsunterstützung im Eigenheim, 2003

[8] Gutschner M., Gnos, S., Nowak S., Potenzialabschätzung für Sonnenkollektoren im Wohngebäudepark, 2010