SELF – THE INDEPENDENT HOUSE

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ABSTRACT

Empa has developed together with Eawag – the Swiss institute for aquatic research - the self sufficient and mobile house SELF. It serves for testing and demonstrating technologies for houses of the future. SELF is a space unit, which is independent from external energy and water supply. It serves two persons for independent living and working, the whole year and everywhere in middle and southern Europe.

Solar modules are producing the energy needed for heating, cooling, ventilation, hot water, light, and appliances. Innovative technologies are reducing the energy and water consumption to a very low level and rain water is collected, purified and recycled.

Together with innovative building industries, Empa wants to explore within the CCEM House2000 project the efficiency limits of modern energy technologies.

1. INTRODUCTION

Our future energy supply has to be based on renewable energy. Heat is no longer a main issue; energy has become an electricity problem. Conventional technologies will not take us where we want to go. Already, our lifestyle and consumer behaviour have taken us far away from sustainable development. To have a chance to control this development and to return to sustainable development, we need to rigorously avoid unnecessary consumption and to make extensive and efficient use of renewable energies.

Energy-independent living and working is the ultimate challenge. Buildings that produce excess energy in the summer and have an energy deficit in winter are not really the solution. Energy cannot easily be shifted from summer to winter. Only if we can operate our buildings without fossil fuels year round we will have a sustainable solution.

Empa has decided in 2008 to face the challenge of finding solutions for operating buildings without fossil fuels. The research institute has created a space module called SELF, which is a research and development platform for investigating and testing new system solutions under real conditions.

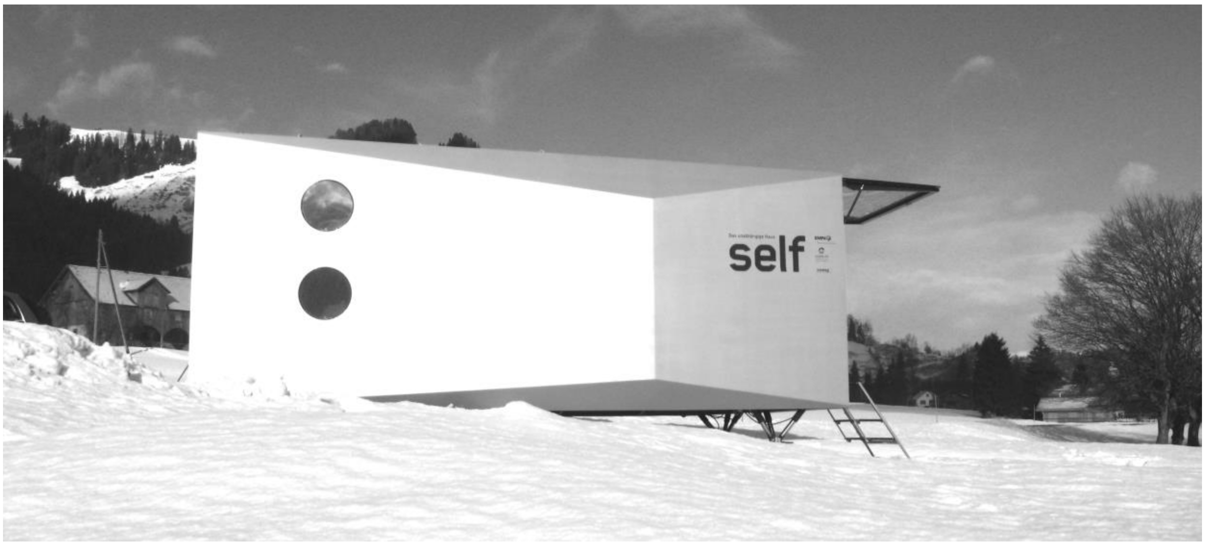

Figure 1: SELF, the independent room cell, during its first winter test at Sihlsee, March 2010, design by industrial designers Sandro Macchi, Björn Olsson

2. REQUIREMENTS FOR THE SELF ROOM CELL

It is difficult to construct highly innovative buildings, since investment risks are high and users' needs often don't match researchers' needs. The ETH Competence Centre Energy and Mobility's House 2000 project, provided an opportunity to build a demonstration house for forward-looking technologies. Empa decided to build not an actual building but a mobile space module that can be used for testing new technologies, as living laboratory for students, for presenting and demonstrating future-oriented technologies, and as lodging for academic guests and researchers. Because of the limited size and the required mobility and flexibility, the challenge was even greater.

Figure 2: Indoor view of the living room with work area

Spatial and technical requirements were based on these potential uses. Optimal use of space and ease of transport played important roles. Key requirements were as follows:

- Room module for comfortable, independent living and working for two persons
- Energy-independent (heating, cooling, ventilation, hot water, and all electrical components) year round in the central European climate zone. At least two weeks of operating energy reserves in case of no solar yield.
- Largely independent from water supply due to rainwater processing and gray water recycling.
- Maximum volume size for transport by truck without escort vehicle (max. width 3.5 m, max. height 3.2 m, weight ca. 6,000 kg).

3. CONSTRUCTION

The independent space module is intended not only to successfully demonstrate new technologies but also to show with its design that new territory is being covered. Every design measure was evaluated in terms of planned uses, space, weight, and energy-related consequences. The detailed results of the comprehensive design studies were constructed in 3-D and visually implemented using CAD [1].

3.1 Highly insulated building envelope

A 10 millimetre (insulating) aerogel mat and 40 mm vacuum insulation panels were used as thermal insulation. Although the overall envelope has some oblique angles, about 90 percent of it could be insulated with standard panels of 60 x 100 cm and half-panels. Custom sized panels were purposely avoided so that defective vacuum-insulated panels can be easily replaced at any time. In a standard section, the structure achieves a U-value of 0.1 W/(m²·K).

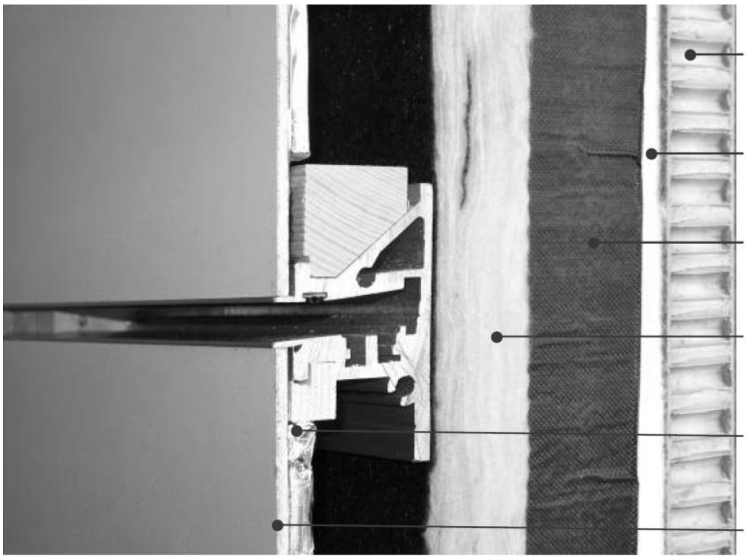

Figure 3: Structure of highly insulated building envelope, total: 150 mm thick, U-value 0.1 W/(m²·K)

3.2 Energy supply

The technological centrepiece is undoubtedly the photovoltaic and battery system that supplies the room cell with electricity. Because only a limited area is available for solar use, the best cells currently available were used. They cover the entire roof and the movable sun shade and have a cell-efficiency of 23%. The extremely light, almost unbreakable glass modules (they can even be walked on) are made of tempered 2 x 2 mm glass.

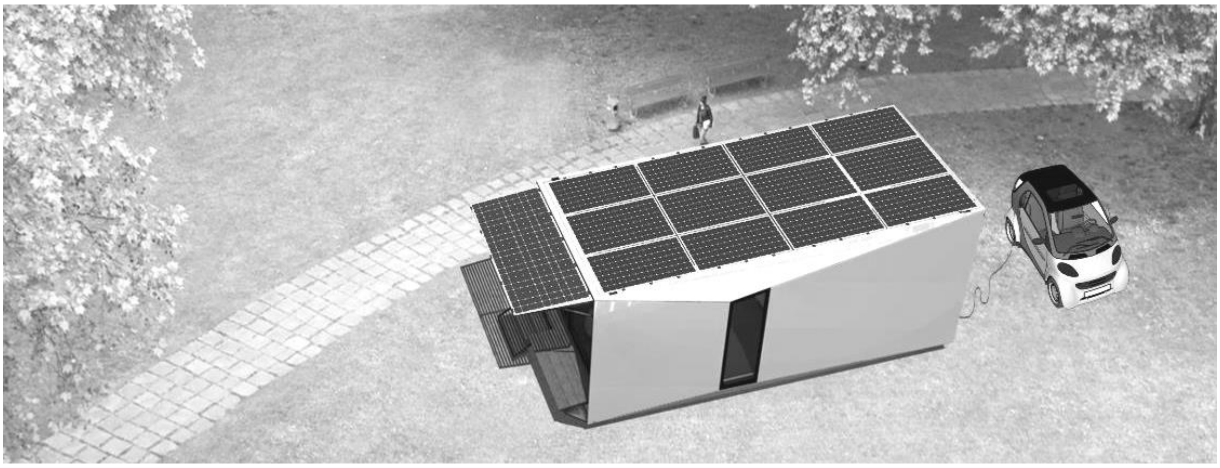

Figure 4: About 20 m² of solar cells cover the entire roof surface and supply 3.75 kW peak

Thermal collectors have not been installed, since the solar panels combined with a heat pump provide in the winter a better yield. In addition, overheating protection and a hot water temperature limitation are not needed in the summer.

Short-term energy storage (12 kWh) occurs directly in the room cell using lithium-ion batteries. For safety reasons and to increase flexibility, the seasonal energy storage is located in a separate supply module. It can also be used to supply energy for other field applications or for charging an electric car. The seasonal energy storage unit consists of lithium-ion batteries (24 kWh) and hydrogen metal-hydride storage tanks (150 kWh). Excess energy from sunny days can thereby be electrically stored or converted to hydrogen via electrolyser. When additional electricity is needed, a fuel cell can create it from the hydrogen. For cooking needs, the hydrogen can also be used directly.

Almost all electrical components are connected to each other via a 230 V-AC bus, which is compatible with the widest range of components. Despite great care during planning, however, electricity management may still be further improved. In particular, the converters, the charging and discharging regulators, and the measurement, control, and regulating electronics still consume too much energy. For an optimal electricity supply, the various components should be better adjusted to each other.

3.3 Water supply

In many countries, clean water is a bigger problem than energy. In order to be also as independent as possible in terms of water, Eawag, the Swiss institute for aquatic research, built a novel water purification system. The system uses the same filter technology as large water suppliers do, but it was designed for small units and in such a way that filter pumps are not necessary.

The drinking water processing system filters up to 100 litres of rainwater a day. Used drinking water (gray water) is collected and routed to a bioreactor, where pollutants are removed and the gray water is filtered. Another 100 litres of recycled water are available as hot tap water for the shower and dishwasher. Only toilet water is collected and periodically emptied. With this system, water autonomy can be increased by a factor of 10, and almost the entire water demand can be covered in rainy areas.

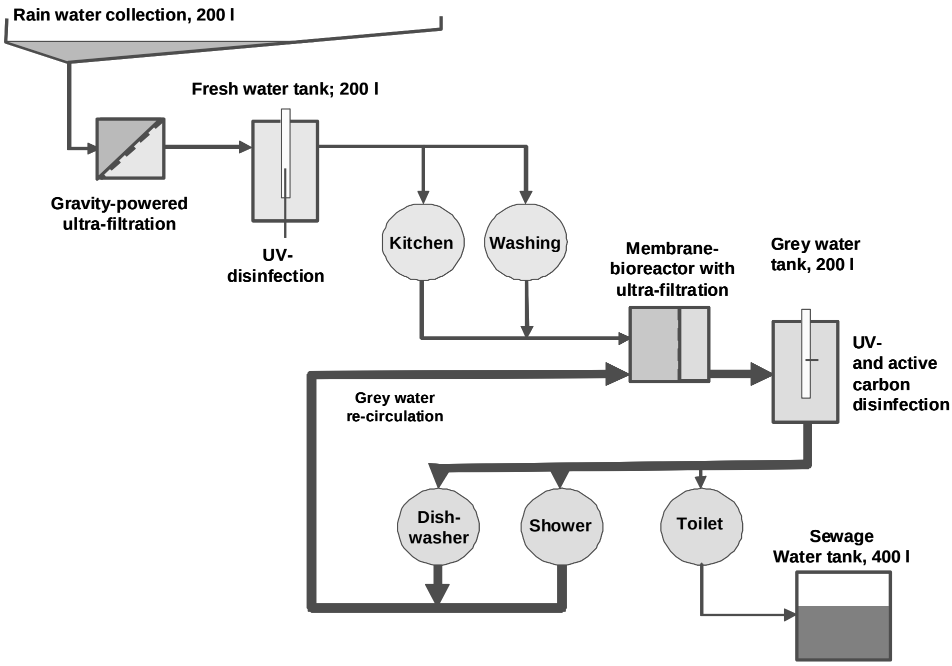

Figure 5: Water system with drinking and gray water processing

4 RESULTS

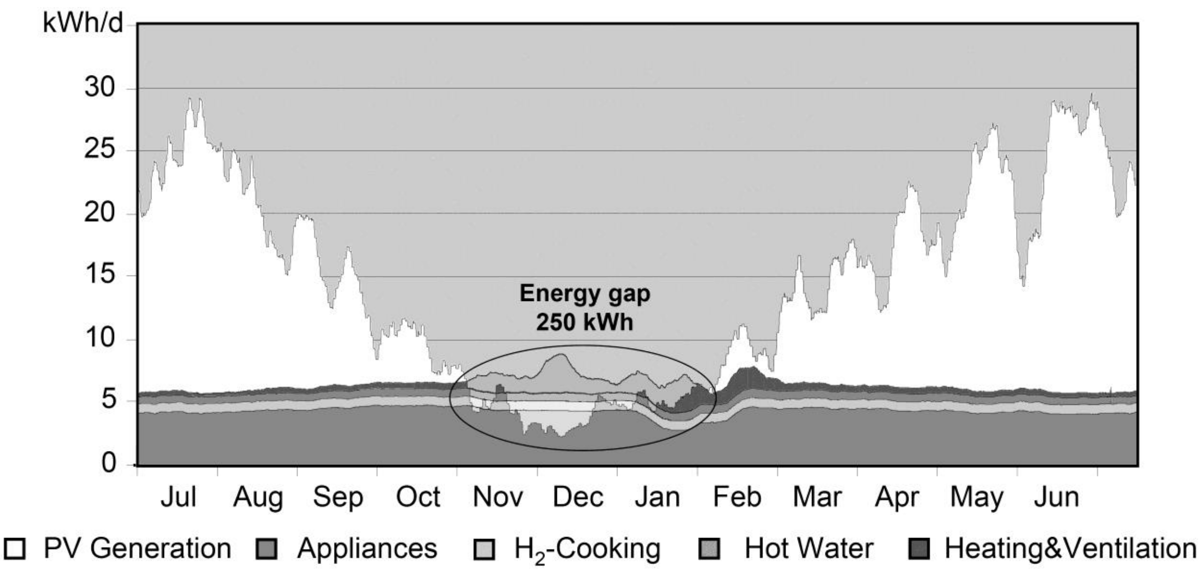

Figure 6: Energy yield and consumption over one year in Zurich. A small supply gap in the winter contrasts with great excess in the summer

The SELF space unit was presented to the public for the first time at Swissbau 2010 in Basel. In April, the Swiss television show Einstein reported on SELF [2]. Unfortunately, on April 2, 2010, the first completed room cell was destroyed in a fire that most likely was started by a technical defect in the battery system. Since then, however, Empa and Eawag have built a second space unit, which has already greatly benefited from knowledge gained from the first prototype.

SELF can especially give us insights into a future energy supply based on renewable energy. The project's objective is not to be representative of future construction, but rather to point out the challenges that still need to be faced.

We have gained the following insights:

- Electricity will be the most important part of energy in the future. In an energy-efficient building, the share of heating in overall energy consumption is relatively small. First, consumption needs to be significantly reduced; only then should renewables be maximized. SELF is designed for an average electricity consumption of just 200 watts.
- In the summer, sufficient energy can be produced quickly, even for the cooling system. In addition, SELF can be used nine months out of the year to charge an electric car for 80 to 100 km a day.
- Cold but sunny winter locations are predestined for solar power. Here, solar energy can mostly cover the energy demand even in the winter.
- If an efficient heat pump is used, only photovoltaic solar energy is advised. Thermal collectors are less efficient and much more complicated to install.
- Seasonal energy storage is still far from being efficient, and new concepts will not be available any time soon. Energy storage must therefore be solved with an energy network.

5 References

[1] Macchi, S., Olsson, B.: Die energieautarke Raumzelle, industrial design thesis, Zurich, University of the Arts, 2009

[2] SF1, Einstein, Energieautarker Forschungs-Container in Schutt und Asche, April 8, 2010, www.sendungen.sf.tv/einstein/Sendungen/Einstein/Archiv

[3] SELF, technical data and project partners, www.empa.ch/self